Factory Planning and Layout

A Report Prepared for Metropolitan Group Policyholders

POLICYHOLDERS SERVICE BUREAU
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FACTORY PLANNING AND LAYOUT

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METROPOLITAN LIFE INSURANCE COMPANY

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FACTORY PLANNING AND LAYOUT

The provision of work areas which are safe and healthful to employees, and the creation of satisfactory operating efficiency, are basic considerations in factory planning and layout. Clean and orderly work places have a direct effect on employee relations. Companies having such conditions usually acquire a reputation of being a good place to work. Plants and allied facilities which are planned to meet the needs of the business tend toward low operating costs.

It is usually difficult and costly to make changes in an arrangement after the construction work is under way, or after the installation of the equipment and machinery has begun. Since the installation drawings for lighting, power wiring, drives, ventilation, exhaust, material handling equipment, process piping and building changes depend on the approved layout, it is essential to proceed with its preparation as early as possible. When the layout is well planned a suitable arrangement results and adequate space requirements are met, installation costs are lower, and loss in production is minimized.

The purpose of this report is to outline the method of conducting studies of planning and layout as applied to both large and small plants in urban and rural communities. It describes the steps involved in a layout study and supplements this with an analysis of underlying principles.

LAYOUT IN SMALL PLANTS

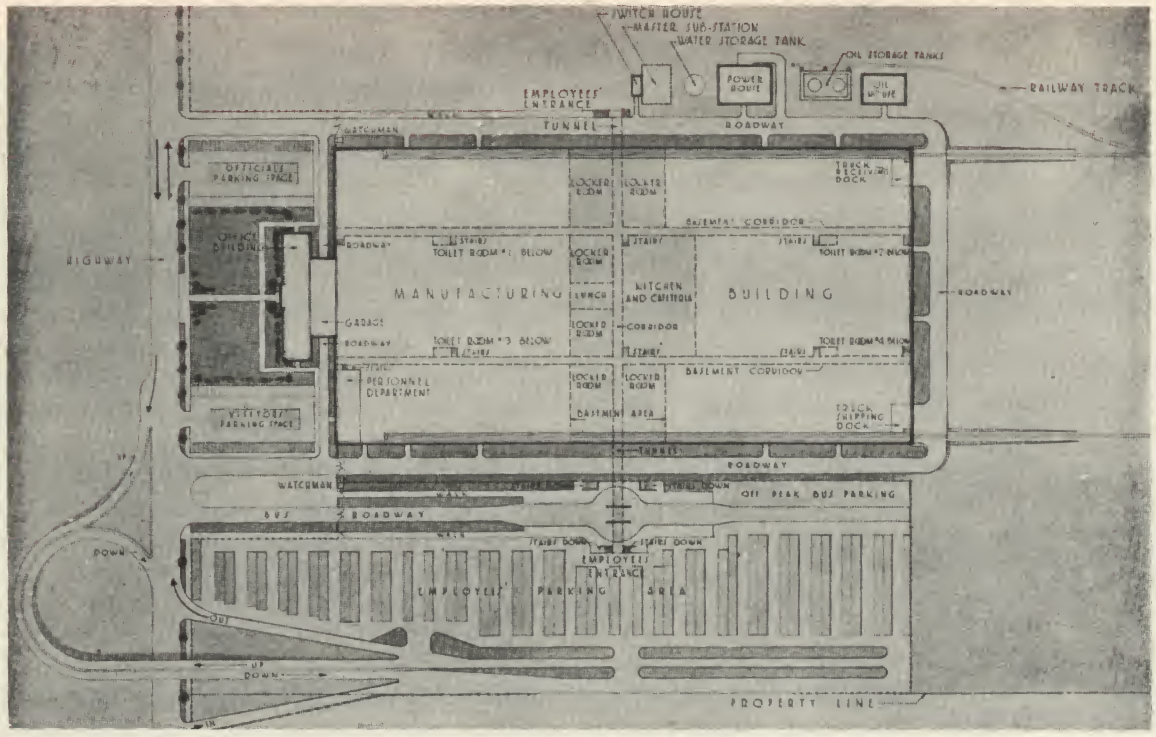
Small factory layouts involve essentially the same problems as those of the large plant. There is the same need for, and analysis of, the flow of the work and conditions under which the product is made. The requirements of the employees are similar and the economies which are available in the large plant can also be had in the small one.

Scale drawings, templets, and models are equally helpful in studying the arrangement with the small factory as with the large one. When the contemplated changes are laid out on paper well in advance, savings can be made and a more satisfactory arrangement will result. Thus, management should find the planning and layout principles given in this report of practical help, irrespective of the size of the operation.

FACTORS AFFECTING FACTORY PLANNING AND LAYOUT

It is well to review the problem from an over-all standpoint in order to formulate a background into which the details may be fitted.

First of all, does the problem deal with an existing plant or one that is to be constructed? New buildings can be designed to meet the needs of the processes. Frequently the building itself is but a housing for the production machinery and personnel, plus space for auxiliary equipment. However, the problem will generally be with an existing factory. If the buildings are already located on the site, it is necessary to fit the equipment and machinery into the available space. In a new factory there will be periodic changes, expanding or contracting a department here and there.



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PLOT PLAN

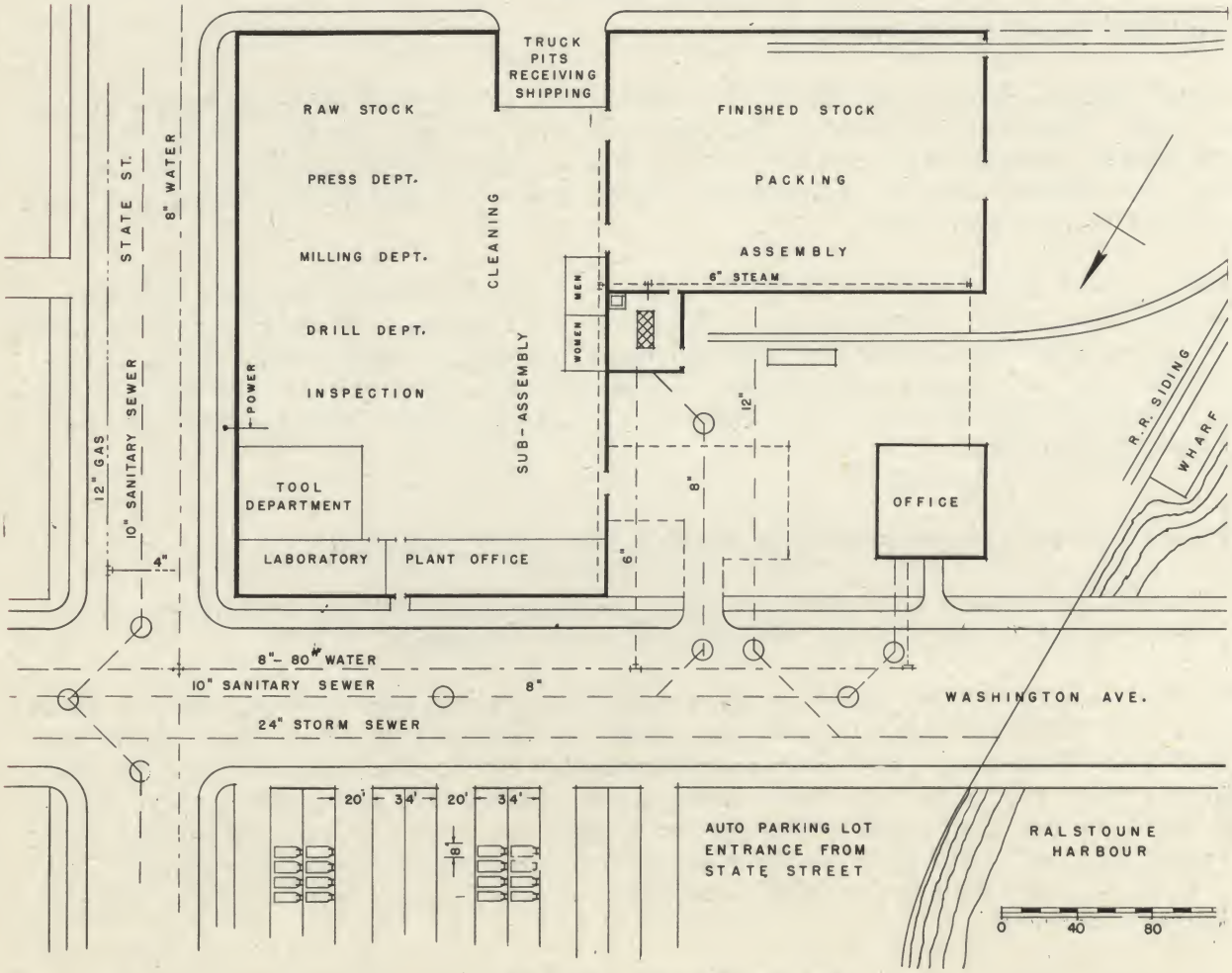


FIG. I - PLOT PLAN

The relationship of the buildings to the street and to the avenues of approach, such as highways, railroads, navigable waterways, and airports should be analyzed. (See Plot Plans - Figure I).

It is essential to know the number and sex of the people to be employed; availability and location of utilities (gas, water, power, light, sewer, steam, oil, and compressed air); the amount of expansion contemplated, and for which products; production routines and sequence of operations; hazards in the industry; and comfort and safety of employees.

When building a new plant or an addition to an existing one, consideration should be given to the type of structure which will best fit the requirements of the business, and in some cases how the new structure will coincide with existing structures or buildings in the neighborhood. It is also important to examine the site on which the new building is to be erected as to soil bearings, rock excavation, grades, fill, and ground water. This is of prime importance, for otherwise an increased cost in conditioning the site and in building design may occur which could be avoided with a more suitable location. The site should preferably be relatively level, at an elevation suitable to the movement of materials in and out of the plant, and with sufficient room for expansion and landscaping. Provision for the parking of employee cars is also essential.

SURVEY OF THE WORK

Before the layout is made it is necessary to review the manufacturing processes and the manner in which the work is being carried on; how the work of one department is related to that of another; the sequence in which the work flows; the amount of material handled, and by what means; the number and type of machines and equipment used, and what the future requirements may be.

For large projects a written description of what is entailed in the making of each product, contemplated product changes, new lines of product, and what is to be accomplished by having a new arrangement are essential factors. This helps to crystallize the thinking and aids those who are not too familiar with the details of the work of the plant in coming to decisions. Job descriptions are also useful in this connection.

It is also essential to discern what provisions are necessary to meet the requirements for auxiliary departments such as general and production offices, foremen's offices, storage rooms, shipping and receiving facilities, lunchrooms, washrooms, locker rooms, first-aid room, entrances and exits for the arrival and departure of employees, engineering departments, and nonproduction and maintenance shops. When insufficient thought is given to these essentials, the new layout is likely to contain features which contribute to loss of time on the part of employees and needless cost in the handling of materials. Thus, working conditions may be created which retard production and cause discomfort to employees. Then too, there are also certain processes constituting hazards which require special study. It is essential to have an arrangement which facilitates supervision of the work. In general, conditions are sought which will contribute to modernization, flexibility, high employee morale, and plant efficiency.

A study of the present arrangement assists in determining where the expansion and changes are most needed and where duplications exist. When machinery and equipment are shown in their present location, they form a background from which to make comparisons (see Figure II). Present areas may be checked

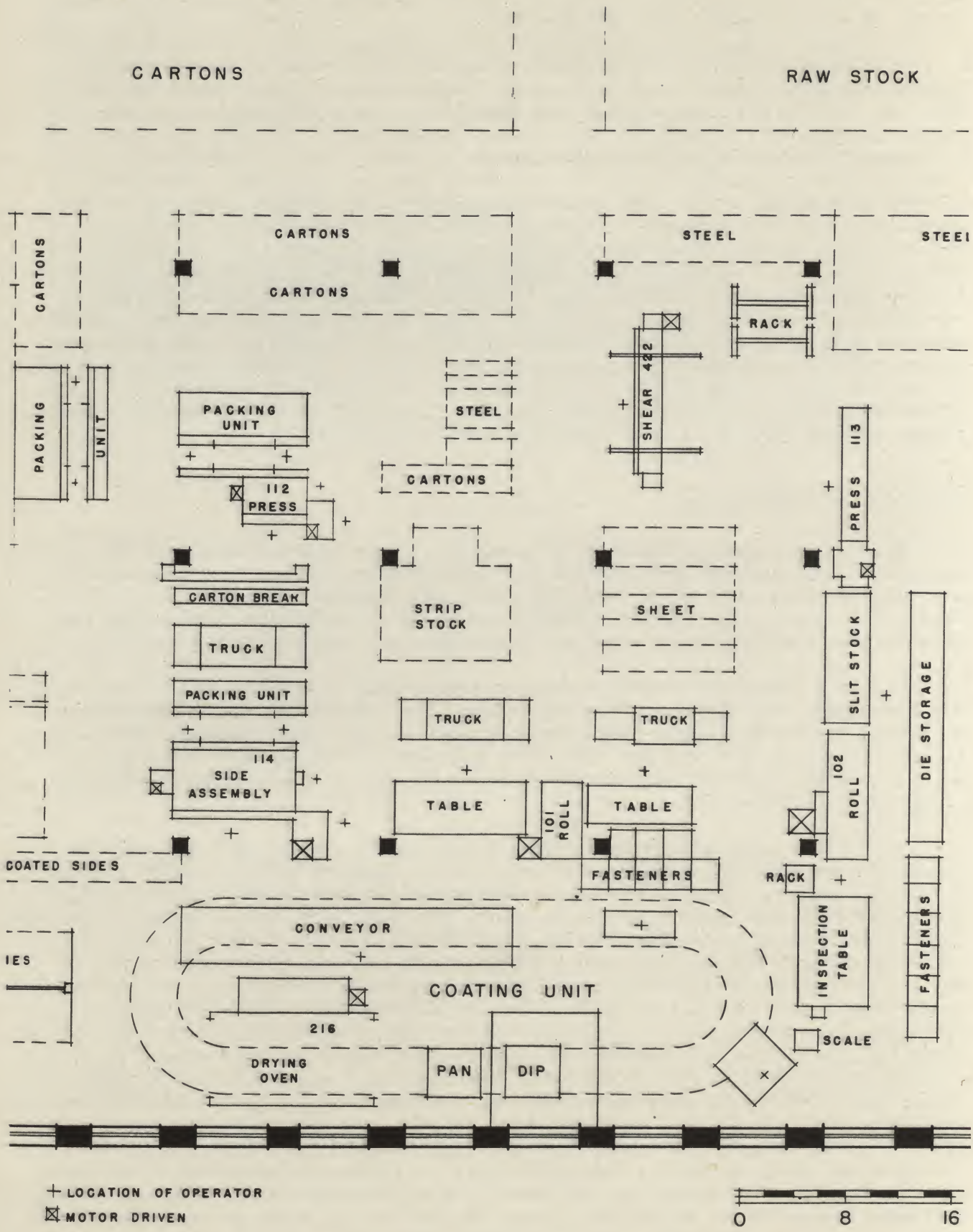


FIG. II - A SURVEY LAYOUT

against proposed areas. The present layout forms the basis for the space templets needed in making the new layout and for reconciling differences of opinion as to the variations between the old and the proposed arrangements. It also shows the clearance between existing equipment and machinery and is helpful in determining where work-in-process areas are needed. It aids in the study of the relationship between operations and how one depends on another. It also serves in the over-all check and guards against omitting items from the new layout.

A layout drawn to a scale 8 feet to the inch (1/8" = 1") has been found convenient, for it is sufficiently large to show the detail for installation purposes and yet not too large to view departments covering large areas. Then too, it is easy to scale with an ordinary rule. However, it may be difficult to present sufficient detail required in intricate processes. A scale of 4 feet to the inch (1/4" = 1") and sometimes a larger scale is preferred for this. A scale of 1/16" to the foot is also used for making over-all presentations of very large plants. When conditions require it, drawings which are made in one scale can be reduced or increased in size by photographic process. Illustrations of the different sizes of layouts are shown in Figures III and IV.

Such scales as 1" = 100' and 1" = 40' (See Figure V) which are used for maps, are both easy to scale with an ordinary rule.

Profiles showing the variation in the elevation of the land and topographic maps are useful for establishing floor levels. Cross-sections and elevations of the buildings are helpful for studying the movement of materials, ventilation problems, light conditions, and head room. These are usually drawn on the same scale as the layouts. Exterior and interior photographic views of the plant are also helpful; likewise, fire insurance plans. (See Figure V).

DATA NEEDED

A listing of all the departments to be accommodated is the first step. When these are put in alphabetical sequence they are helpful for reference and checking purposes. The next step is to obtain a tabulation of the present and future personnel by departments, both as to men and women, as shown in Table A on page 13.

The information concerning the personnel is needed in order to have criteria from which to provide suitable facilities for employees as referred to on page 7 under Survey of Work.

Machinery and Equipment Schedules are prepared which contain machine reference numbers, location (department, building, floor), machine description, and quantity. These include new machinery, equipment on order, and contemplated equipment purchases. All of this information is helpful in calculating the areas required for manufacturing, determining the amount and kind of power, checking floor loads and elevator capacities, and answering questions relating to equipment foundations, floor construction, ceiling clearances, drains, piping, ventilation, drives, conveyors, and the disposition of waste materials. A suggested form of tabulation is shown in Table B on page 13.

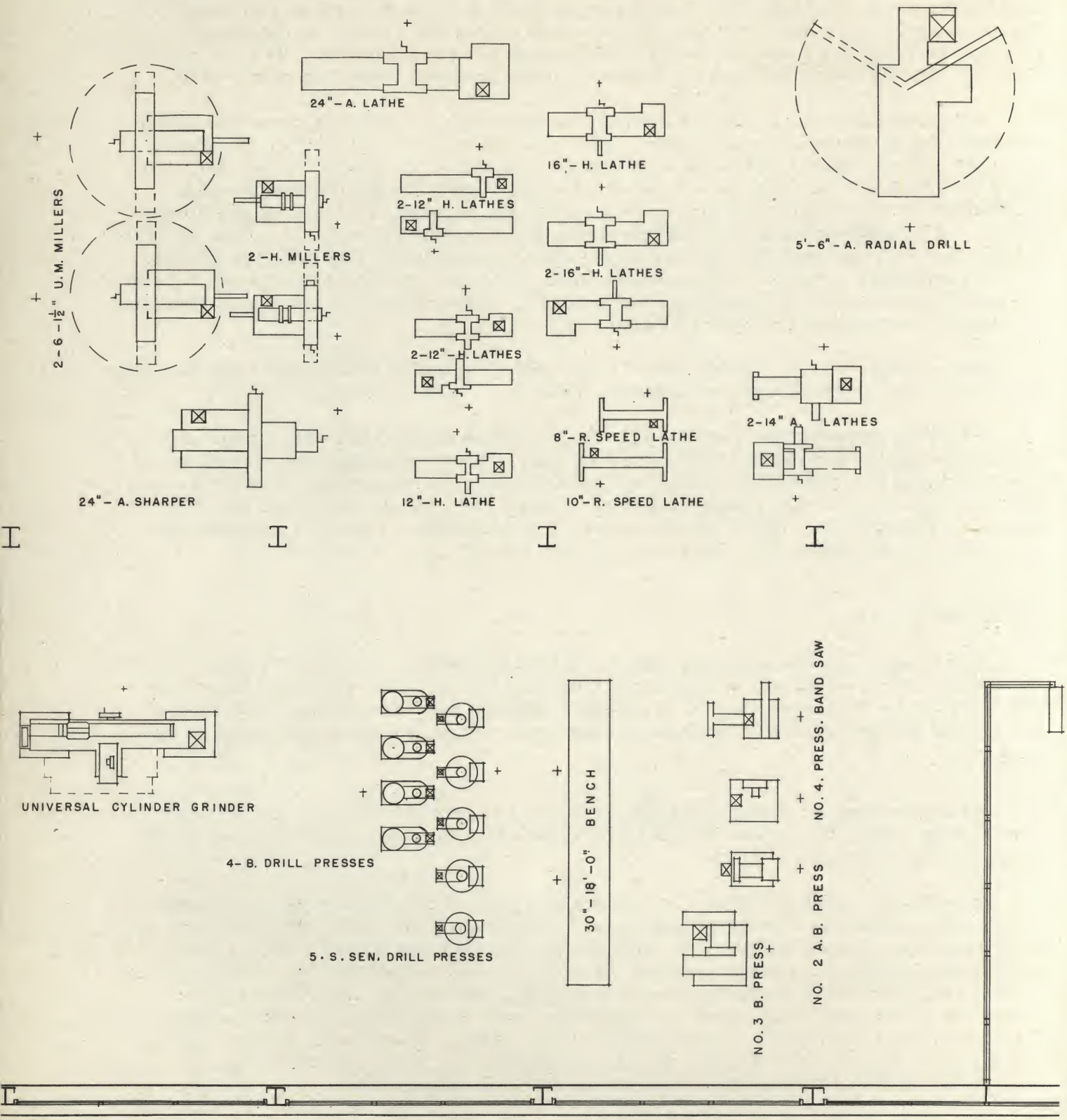


FIG. III - ONE-EIGHTH SCALE LAYOUT

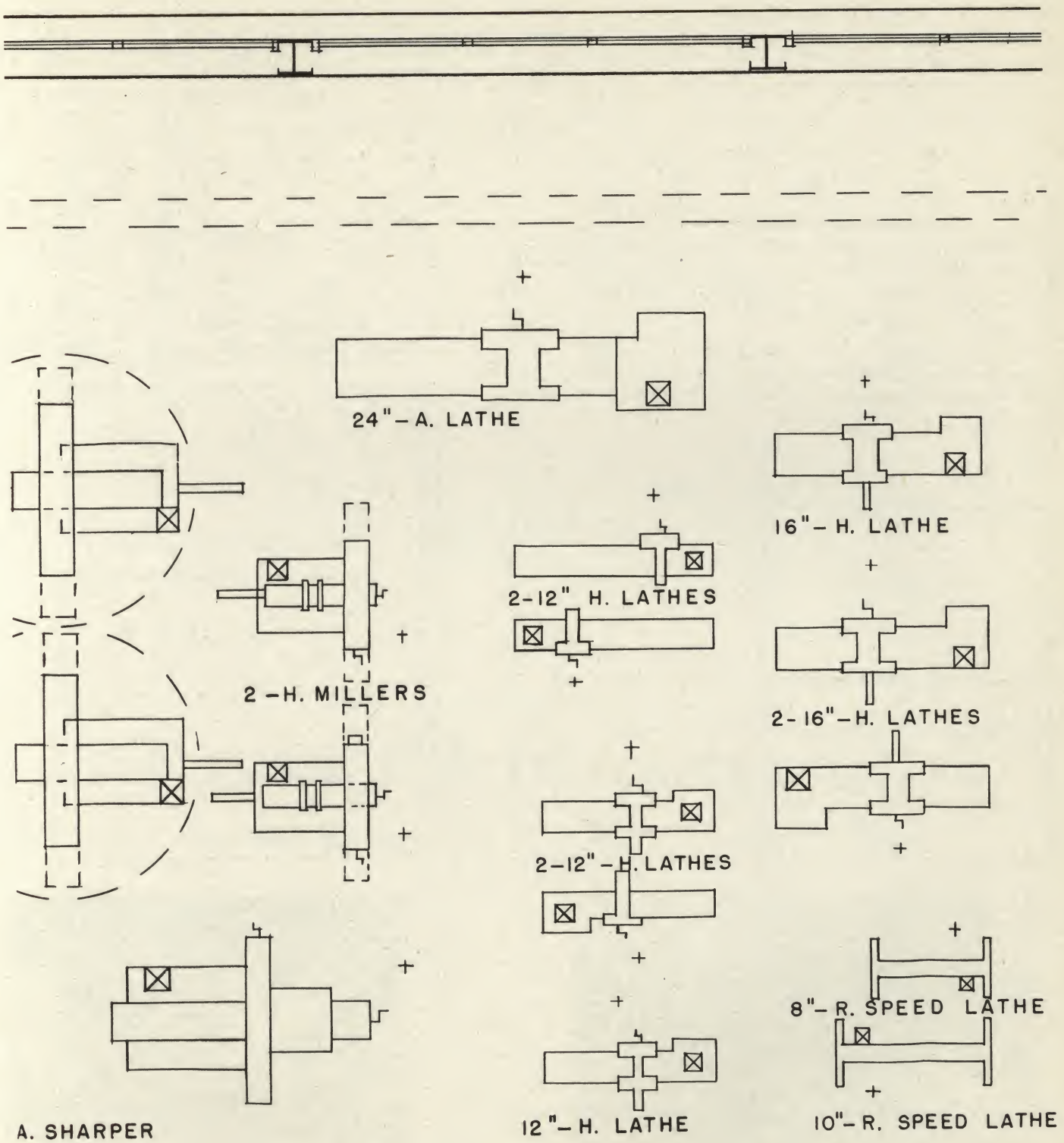
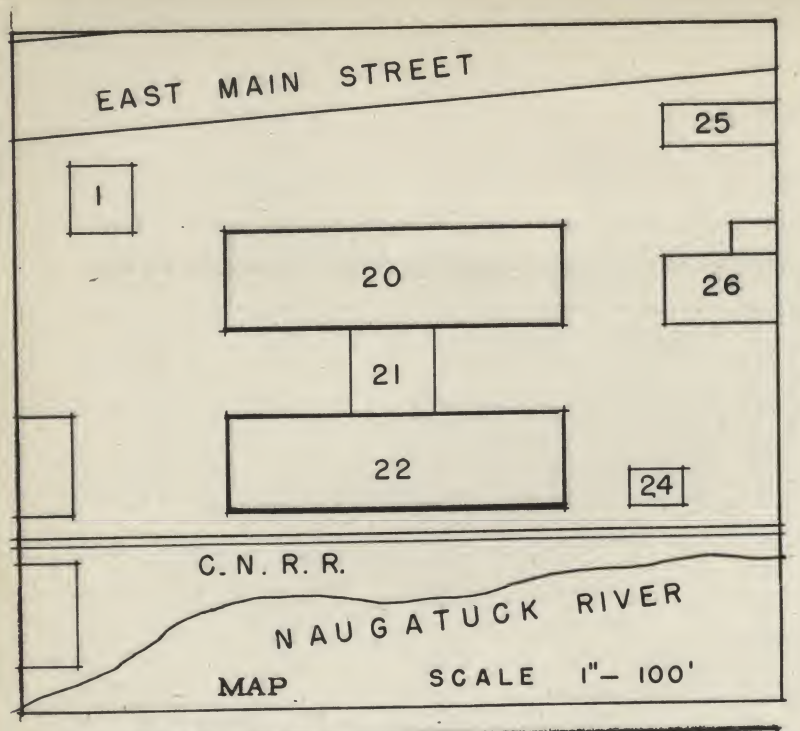
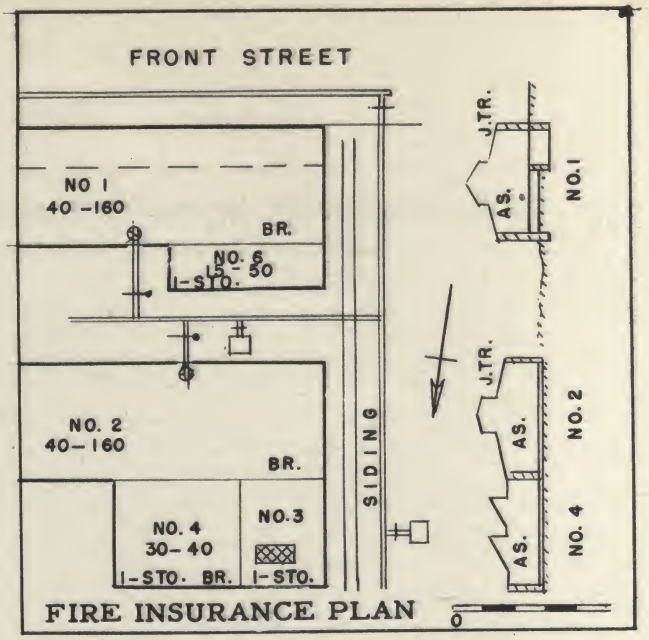
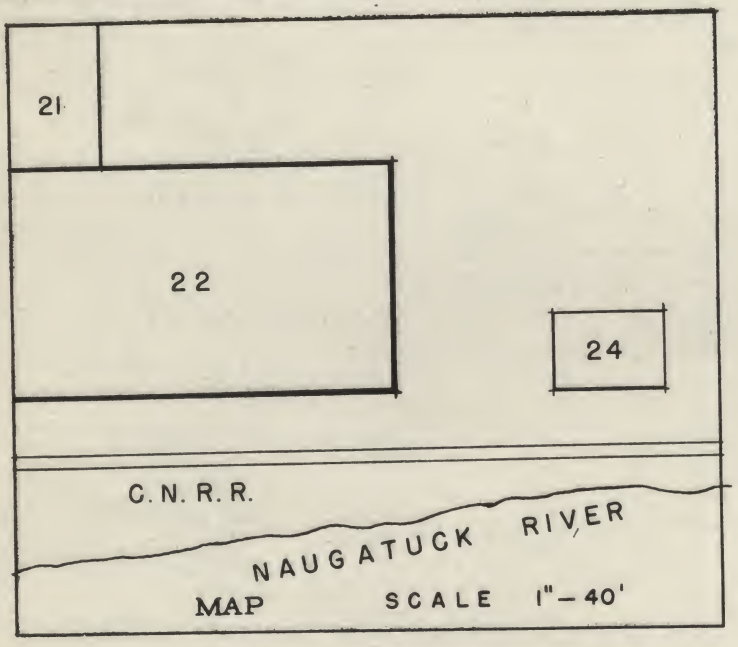
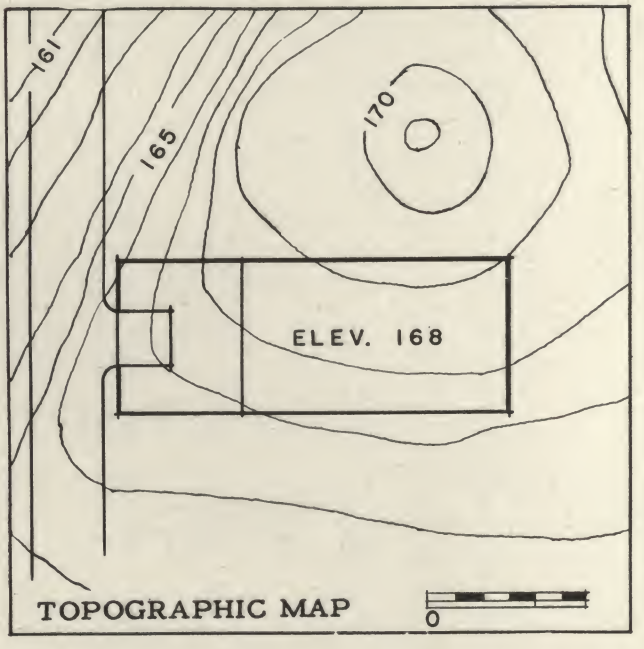


FIG. IV - ONE QUARTER SCALE LAYOUT









Courtesy Lockwood Greene Engineers Inc.

EXTERIOR VIEW

Courtesy Architectural Record

INTERIOR VIEW

FIG. V

TABLE A

Tabulation of Personnel

General Departments	No.of Men	No.of Women	Total	Factory Departments	No.of Men	No.of Women	Total
Engineering	-	-	-	Bench	-	-	-
First Aid	-	-	-	Drill	-	-	-
Lunchroom	-	-	-	Grinding	-	-	-
Maintenance	-	-	-	Inspection	-	-	-
Office	-	-	-	Press	-	-	-
Personnel	-	-	-	Receiving	-	-	-
Production Control	-	-	-	Shipping	-	-	-
Protection	-	-	-	Stock Room	-	-	-
Research	-	-	-	Supervisors Office	-	-	-
Standards and Methods	-	-	-	Tool Crib	-	-	-
Steam Plant	-	-	-	Toolroom	-	-	-
Transportation	-	-	-	Warehouses	-	-	-
etc.	-	-	-	etc.	-	-	-
Total	-	-	-	Total	-	-	-

		Men	Women	Total
(For day shift only)	Grand Total--	-	-	-
	Percentage--	-	-	-

TABLE B

Machinery and Equipment Schedule

Reference Number	Department	Building Number	Floor	Machine Description (M = Motor Drive)	Quantity
295	Milling	1A	1	B.& S. No. 12 Miller (M)	1
296	"	1A	1	Cinn. No. 1-18 Miller	1
---	-------	--	-	----------	-
---	-------	--	-	----------	-
654	Press	2B	1	Bliss No. 73A - P.P. (M)	1
655	"	2B	1	Standard No. 93-P.P.	1
---	--------	--	-	----------	-

Reference numbers may be identification symbols which are usually attached to the equipment for insurance or production purposes.* At other times the reference numbers are a numerical sequence used for making the study. When listing machines by departments it is well to have all the machines in the same department grouped together. With machine descriptions it is helpful to designate the make, size, and kind, and to have the same type of machines within the department listed together.

*For further description refer to "Accounting for Plant and Equipment," Policyholders Service Bureau, Metropolitan Life Insurance Company.

Process diagrams and material flow charts (see Figure VI) which show the percentage of work entering and leaving each department, together with its source and destination, are useful for the following purposes:

1. To visualize how the work of one department ties into that of another.

2. To indicate the amount of material moved from one department to another, and the order in which it is moved.

3. To determine the degree to which individual departments are self-contained.

4. To show those departments which are service units.

The material flow charts (a composite of the departmental material flow charts) are also useful when developing department relation diagrams which are used for incorporating into the layout those departments that would be best located adjacent to each other (See Fig. VII). Department relation diagrams are of particular value when designing an entirely new plant.

It is helpful to know the tonnage by classes of incoming materials (raw, semifinished, and finished) which will be purchased during the year and delivered to the factory. When this is given on a quarterly basis it provides a convenient measure for judging the kind of material-handling facilities needed.

A forecast of future needs is essential for determining what departments are likely to expand or contract. This is made through conferences with executives and employees familiar with the operation of the business. As the tabulations and schedules are being prepared it is also advisable to secure the opinion of those who supervise the operations in the departments where the work is performed and others familiar with the practical operating methods. Process, time study, and work simplification engineers can also be helpful. Better and less expensive ways are often developed through such exchange of ideas, all of which tends to bring about conditions and arrangements from which substantial savings may be made.

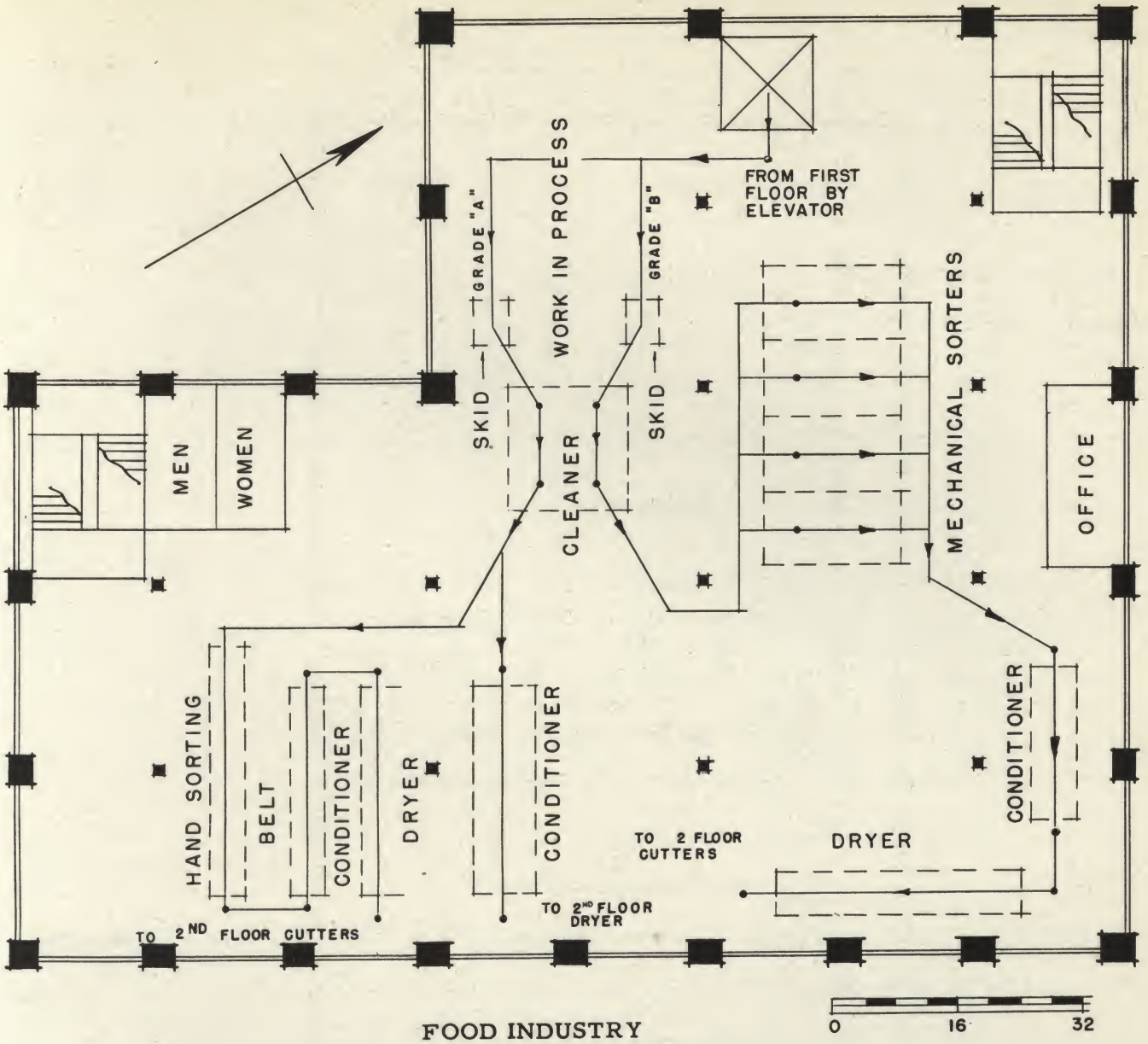
SPACE REQUIREMENTS

For preliminary studies and the designation of department areas, factory space requirements may be stated in terms of square feet per department or section. This is usually tabulated in the form shown on page 17.

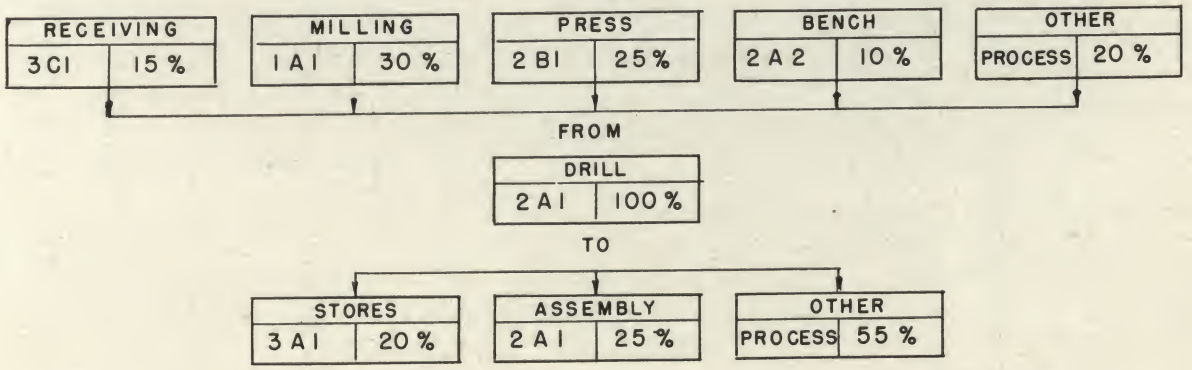
Departments are listed in alphabetical order, as indicated on page 13. Those departments in which more than one major task is performed should show the breakdown by operations, such for example as the following:

Press Department

- Press work
- Tool crib
- Work-in-process
- Bar stock
- Strip stock
- Roll stock



FOOD INDUSTRY
PROCESS DIAGRAM



MATERIAL FLOW CHART

FIG. VI

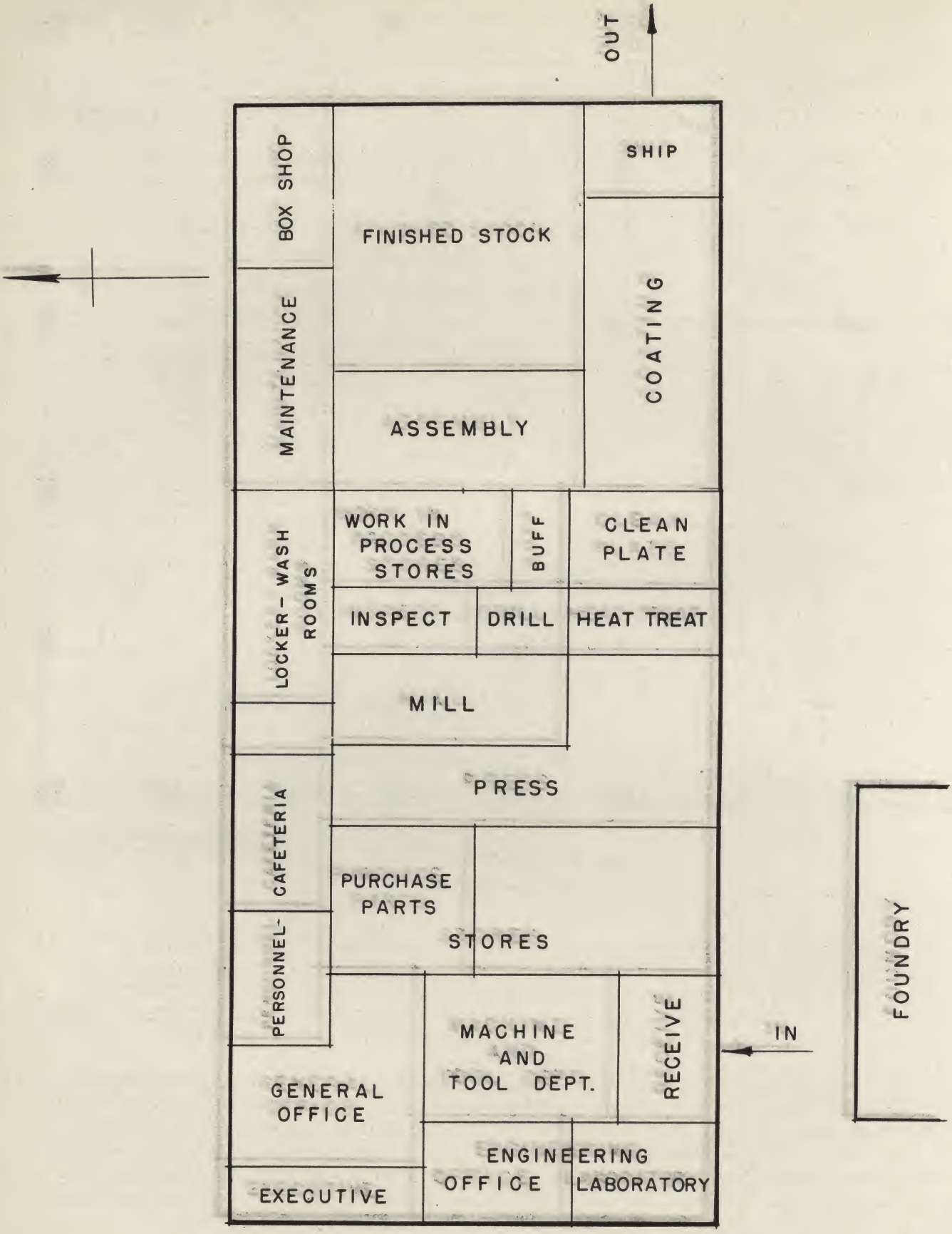


FIG. VII - DEPARTMENT RELATION DIAGRAM

Space Requirements

Department	Operation	Present Area	Future Area	Scheme I	Scheme II
Bench	Burr	850 sq. ft.	1,200 sq. ft.	1,300 sq. ft.	1,140 sq. ft.
Drill	Drilling	2,000 " "	2,500 " "	2,600 " "	2,100 " "
----	----------	----------	----------	----------	----------
----	----------	----------	----------	----------	----------
Press					
"	Press work	4,300 sq. ft.	4,800 sq. ft.	4,900 sq.ft.	4,700 sq. ft.
"	Tool crib	1,200 " "	1,200 " "	1,300 " "	1,200 " "
"	Work-in-process	900 " "	1,500 " "	1,600 " "	1,400 " "
------	----------	----------	----------	----------	----------
Receiving	----------	1,250 " "	1,600 " "	1,750 " "	1,500 " "
Total		-----	------	-----	-----
Miscellaneous					
Aisles, ramps Columns, walls Wash and locker rooms		1,500 sq. ft.	3,000 sq. ft.	3,100 sq. ft.	2,900 sq. ft.
Elevators and stairs		500 " "	500 " "	500 " "	500 " "
Total		------	-----	------	-----
Grand total sq. ft.		------	------	------	-----

The preceding tabulation provides a convenient manner for a summarization and contains sufficient detail to identify related items. A clearer picture of the economical utilization of space is had when the miscellaneous items are set apart from those used for manufacturing purposes, as shown above.

Factors which affect the space needed, include the following:

1. Nature of the available space. In the manufacture of many products, large open space with wide column spacing, in single or multi-story buildings, is preferable to small and irregularly shaped areas. With the former a flexibility is afforded in the manner of layout. It is favorable to good working conditions and has advantages in the movement of materials and in ease in supervision.

2. Product manufactured. The space requirements for any given machine will vary according to the industry. The amount of space needed for the storage of raw materials and finished products, work-in-process areas, aisle widths, work space around machines, and warehousing will also vary. Production shops have different requirements from jobbing shops, and the extent to which gravity flow enters into the process affects the space requirements, and has a bearing on the type of building needed.

Computing Area Requirements

Based on the factors mentioned above the approximate areas required can be computed by one of the following methods:

1. By assigning area values to each machine or piece of equipment and then adding up the total of these plus an allowance for aisles, work space, and expansion.

2. By obtaining scale drawings of each department or section, which is to be included in the study. These should show the present location of all the machinery and equipment, as mentioned on page 7 and indicated in Fig. II. Dimensions of the area occupied by each operation can be scaled off and the space requirements computed in the manner called for under the headings of the tabulation shown on page 17, with percentage allowances made for the expansion or contraction of operations.

3. Similar results can be had by superimposing the layout of existing departments, in whole or in part, on an outline drawing of the space which is being considered for a new location. Both the layout and the drawing need to have the same scale and they should be in contrasting colors, such as a negative photostat of the existing layout superimposed on a blueprint of the outline drawing mentioned above. (See Fig. VIII). This is a useful approach to problems relating to rough layout and allocation of space.

When the final layout is being prepared it is necessary to make a piece-by-piece arrangement by the use of templets or models which represent machinery and equipment.

ALLOCATION OF AREA

After the departmental areas have been established, with due allowance for expansion, the next step is to allocate the area needed for each department to its logical place in the new layout.

When allocating the areas it is helpful to have knowledge of the following:

1. The manner of receipt and delivery of goods into and out of the plant.

2. The relationship between departments, both manufacturing and general. (See Figs. VI and VII).

3. Methods of handling materials between operations within the same or other departments.

4. Processes requiring special plumbing facilities. For example: Acid drains or treatment equipment for the disposal of factory waste which is prohibited by ordinance or by expediency from being dumped in the sanitary sewer system or into streams. Provisions for these installations, if needed, should be made.

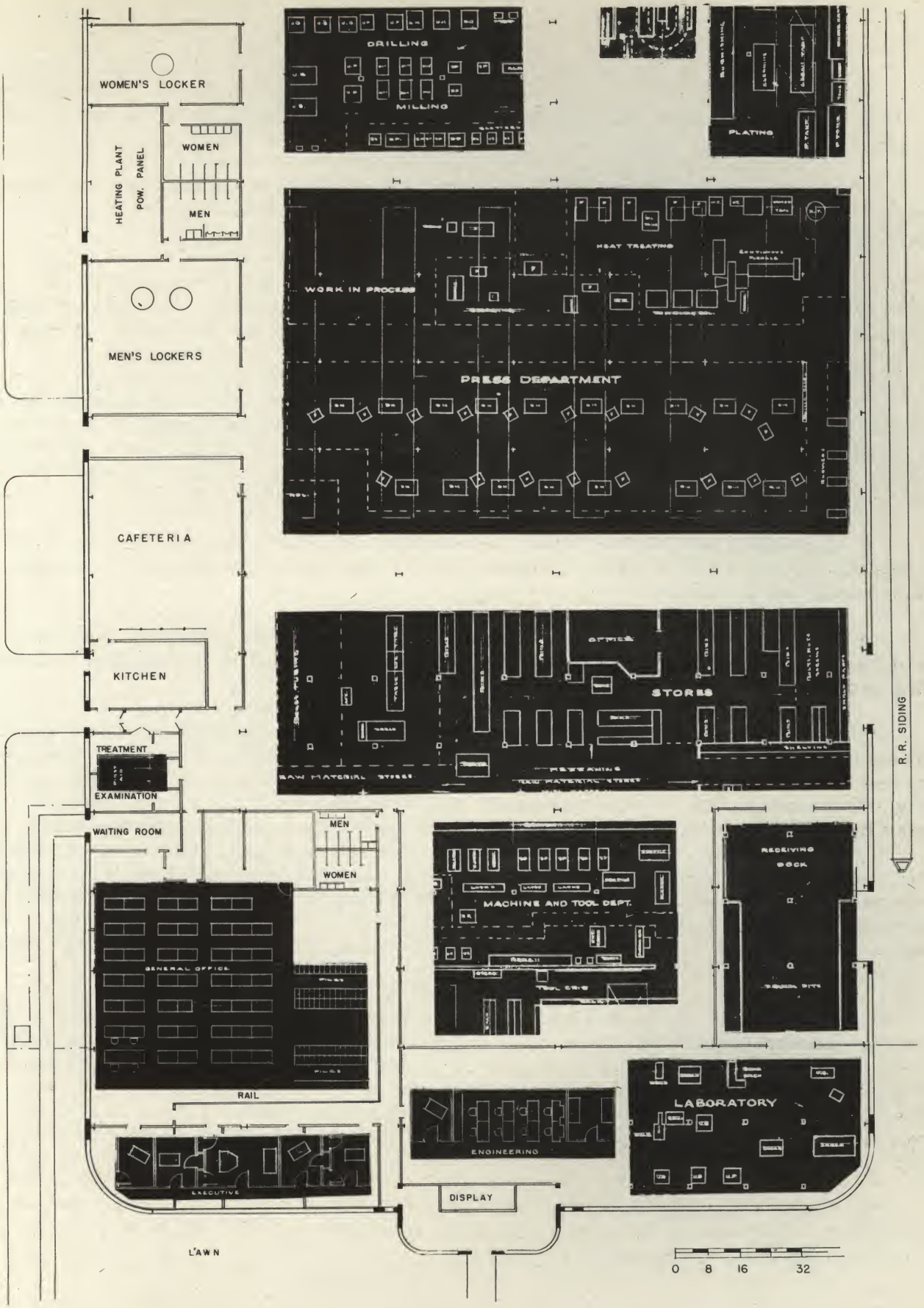


FIG. VIII - AREA REQUIREMENTS

5. The departments and sections where large numbers of people work close together.

6. The departments and sections in which particularly good light is essential. Is natural light available or will special artificial illumination be required?

7. Places where work-in-process and storage areas are needed so as to hold the work between operations and minimize the handling. Main aisles suitable for the movement of material through the plant and for the safety of employees.

8. Situations where long-term savings can be made, either in greater length of life or in lower repair cost, by making high-quality installations at an increased initial outlay. The greater initial cost may be offset by lower operating cost. This, however, may not apply to equipment having a high obsolescence rate or where the need for the product does not recur regularly.

9. Instances where small service machines could be provided so as to obviate the necessity of sending components to other departments to have minor operations performed.

10. Floor-load requirements. It may be necessary to locate certain large and heavy machines on the ground floor; otherwise, the cost of changes in building design or for reinforcing would be excessive.

11. Processes which require special treatment can often be located adjacent to each other and so affect economies in installation. Thus, if a group exhaust system will serve, the cost of the installation may be minimized and the operating and maintenance expense lowered. By following such a plan the flow of air may be away from that portion of the space where the main manufacturing is carried on, and toward the potentially hazardous processes, thus causing fresh air continually to enter the main work space. Conversely, sections whose operations might present health hazards can sometimes be placed in areas where a minimum of mechanical equipment is needed in the ventilating system, as against an outside wall, or under a roof ventilator, taking advantage of the natural air movement.

12. Location of entrances and exits. In the interest of plant protection additional expense for watchmen may be required in plants with two or more entrances. On the other hand, if a plant has only one entrance and the distance from this entrance to the work area is great, there may be additional payroll expense for the time spent by employees in going from the entrance to their places of work.* Naturally, the importance of these problems increases with the size of the plant.

13. Space which had been considered unsuitable for manufacturing and office purposes. Can this be utilized to good advantage by the installation of modern lighting and air-conditioning systems?

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*See U.S. Supreme Court decision of July 10, 1946, in case of Anderson et al vs. Mt. Clemens Pottery Company.

LARGE-SCALE ARRANGEMENTS

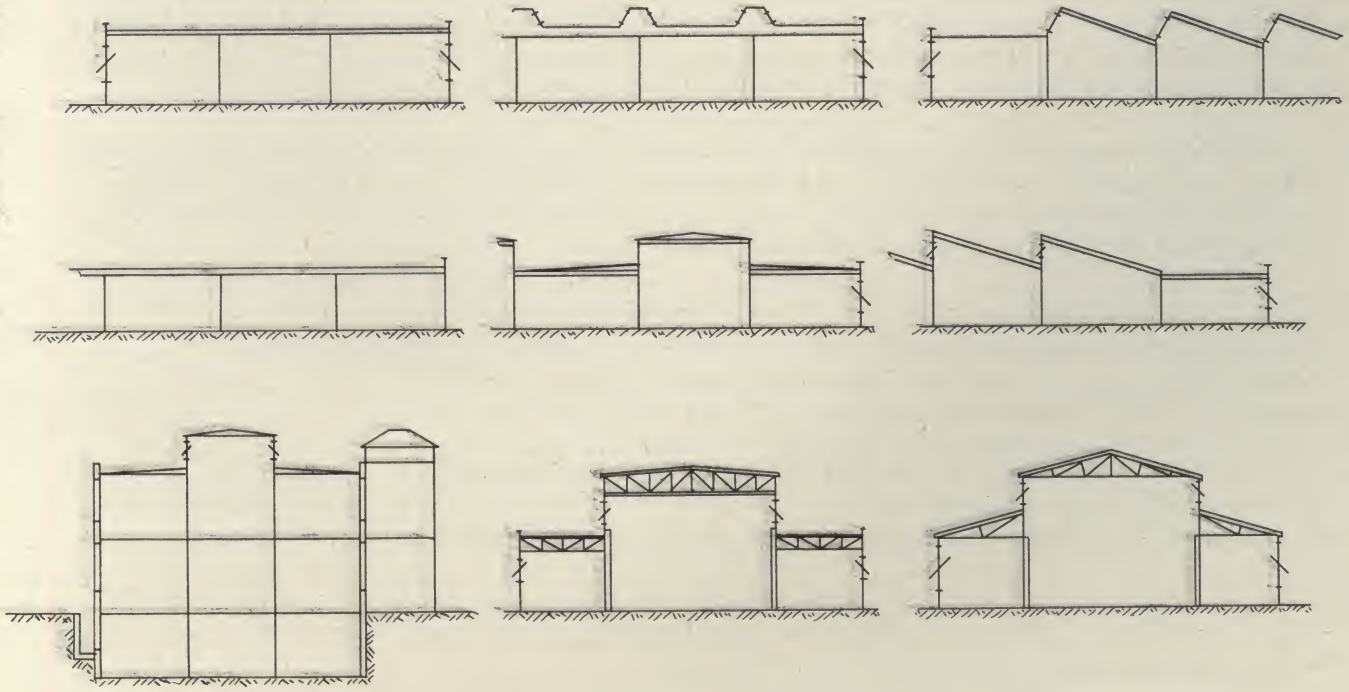
Special problems in the redistribution of space in the larger plants are faced by concerns that occupy multi-story buildings or several buildings. There is frequently idle or partly utilized space on each floor or building, but not in sufficient amounts or in the right places to satisfy the needs of all departments. This requires a floor-by-floor or building-by-building analysis of the available space, the comparison of this space with the expansion requirements of the departments and determination of the amount that each is over or short. The result will indicate the extent to which departments must be shifted in order to utilize the space to maximum advantage. The final plan may require a rearrangement of departments not normally involved in the change in order to make space available to those departments which have need for expansion. The following illustrates the method used:

Analysis of Space Requirements, in Square Feet, and Vacant Space by Floors

Floor or Building	Vacant Space	Expected Requirements	Deficiency	Excess
1	3,510	2,150	-	1,360
2	-	4,800	4,800	-
3	2,180	3,460	1,280	-
4	7,600	5,290	-	2,310
etc.	-	-	-	-
Total	- -	-	-	-

BUILDING TYPES

As an aid in the location of certain departments, and for determining which building is best suited for a particular process, cross-section diagrams of the buildings are helpful. Some general types follow:



PLANT LOCATION

When seeking the location for a plant, either for erecting new or acquiring an existing one, the following factors have a bearing on the selection. The building and location selected may influence the general arrangement of the factory and auxiliary facilities:

1. Size of the community. (a)
2. Labor supply - skills, and the amount available (a)
3. The location of competitors. (a)
4. Housing for employees. (a)
5. Available service industries. (a)
6. The location of customers or the market to be served. (b)
7. Manner of warehousing raw and finished product (at the plant or elsewhere). (b)
8. Location and source of raw materials. (b)
9. Transportation facilities adequate for personnel and freight. (b)
10. Availability of utilities (power, water, gas, sewerage disposal, fuel). (c)
11. Local ordinances and regulations. (c)
12. Climatic conditions. (d)
13. Space for adequate expansion. (e)
14. Land values and the tax situation.
15. Public improvements - schools, police and fire protection.
16. Market, social and religious provisions for employees.
17. Presence of suitable financial facilities for both employees and the industry.

(a, b, c, d, e) Items that bear a direct relation to plant layout.

(a) Where there is insufficient labor supply or the competitors offer more favorable conditions, it may be necessary to establish branch plants or subcontract some of the operations, thus decreasing the size of certain departments.

(b) Where the customers are located within trucking distance the factory may become the warehouse, thus larger warehousing facilities are needed. When the source of raw material is near by the supplier may do the warehousing, therefore space for storage can be minimized.

(c) Where utilities are inadequate it may be necessary to make provision for them at the plant. Local ordinances may limit what may be discharged into sanitary sewers and streams. It therefore may be necessary to provide space in the factory for special treatment facilities.

(d) Climatic conditions have a definite bearing on the heating, ventilating, and air-conditioning requirements. In some localities special conditioning equipment may be needed in connection with the manufacturing processes.

(e) In arranging machinery and equipment in a factory it is always expedient to lay it out with a view to expansion, thus reducing the need for subsequent major rearrangements.

ROUGH LAYOUT

The preparation of the layout involves three steps:

(a) Obtaining a floor plan of the space to be occupied.

(b) Preparation of templets or models.

(c) Arrangement of the templets or models on the floor plan.

Floor Plan

In the case of a new factory or an addition to an existing one, preliminary or outline drawings of the plant will serve as a background into which the new layout may be fitted. (See Fig. IX).

The drawings should show location of walls, windows, doors, columns, permanent partitions, and heating equipment (radiators and unit heaters). Sufficient information is needed to make it easy to discern where structural features of the building could interfere with the process equipment. When these are known building changes can be avoided, which otherwise would be necessary if insufficient thought was given during the making of the rough layout. The scale used in the floor plan should be one of those previously described on page 9, either 1/4 inch, 1/8 inch or 1/16 inch per foot.

Templets

A templet is prepared for each machine or piece of equipment, drawn to the same scale as is used for the floor plans. (See Fig. X) Two forms of templets are in use: The Block and the Two Dimensional. The former indicates the base area occupied by the machine (usually in rectangular form); the latter shows the outline of the machine in detail, including travel of moving parts, together with drive, work stands, tote boxes, trucks, etc. Templets are usually made of a light cardboard or heavy grade of tough, pliable paper. The present layout, as described on page 7, forms a source for templet sizes and spacing requirements. Separate colors are often used for differentiating between various types of equipment. Color schemes are also used to note the different departments and to differentiate between old and new or future equipment. It is frequently necessary to select colors which will photograph differently. Colors which produce different shades when reproduced are salmon, fawn, yellow, green, and cherry. When making a photoprint it is well to use a color screen to bring out the contrast. A layout in contrasting colors assists in visualizing the arrangement.

Models of the machinery and equipment, made to the same scale as the drawings, are also used. These have the advantage over templets of presenting objects in the third dimension. This is an aid for visualizing clearance in and around machines as well as height requirements. In some instances models are used to supplement templets when studying intricate operations. (See Fig. X)

A rubber base or nonhardening cement is commonly used for attaching templets or models to the floor plan. The templets can be taken off easily, or moved from place to place as changes in the layout are made. An arrangement of templets on a floor plan is shown in Fig. XI.

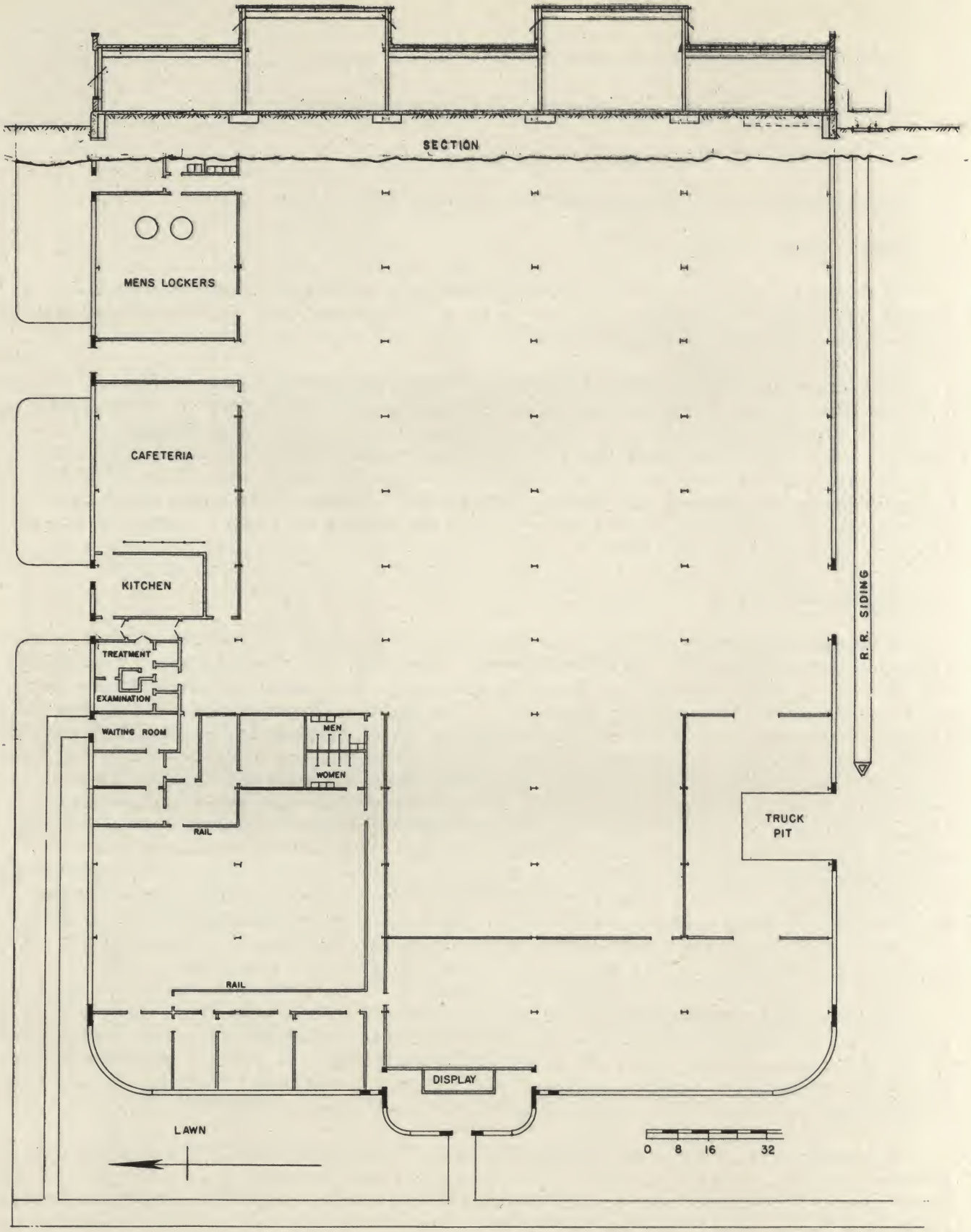
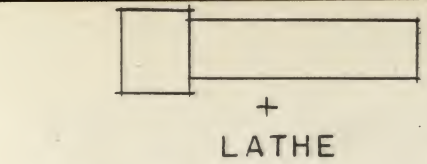
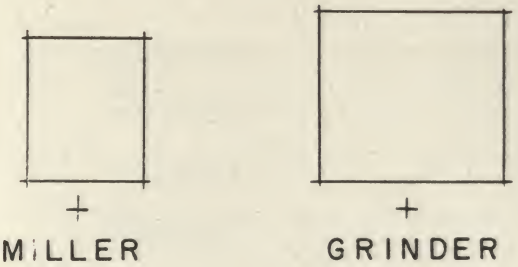


FIG. IX - FLOOR PLAN



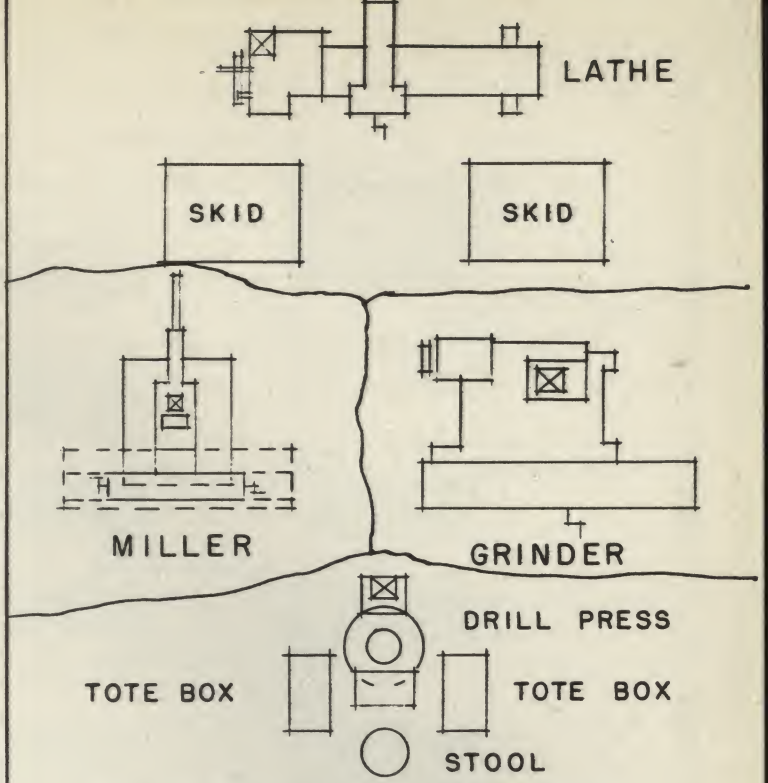
LATHE



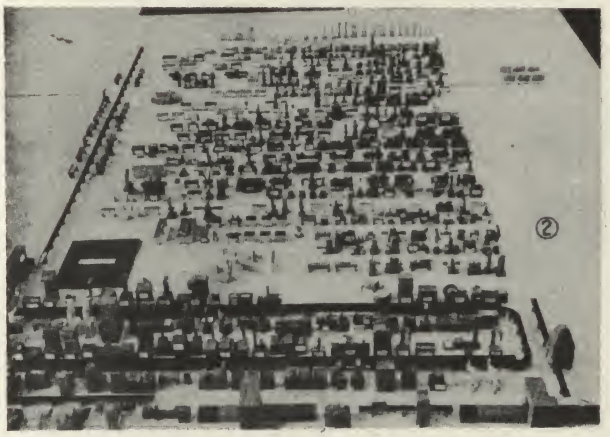
MILLER GRINDER

DRILL PRESS

BLOCK TEMPLATES

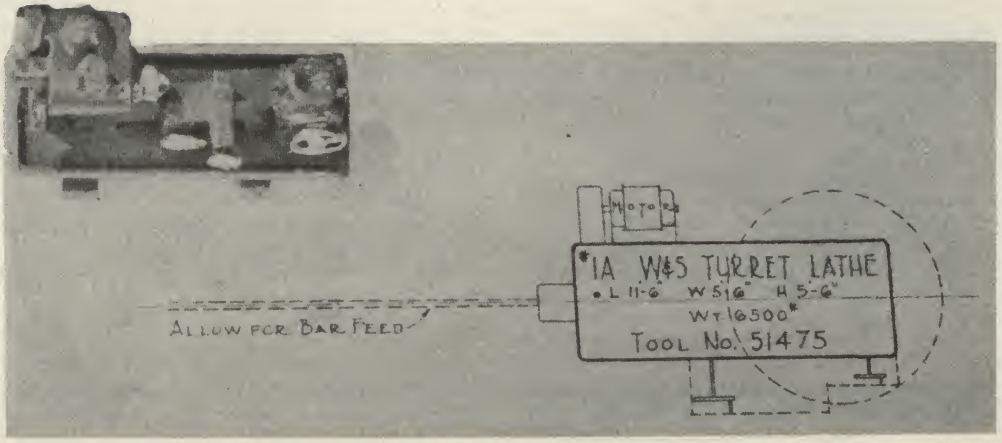


TWO DIMENSIONAL TEMPLATES



Courtesy - Steel

MODELS



Courtesy - Mechanical Engineering

FIG. X

Three Dimensional Model For Use With Two Dimensional Template

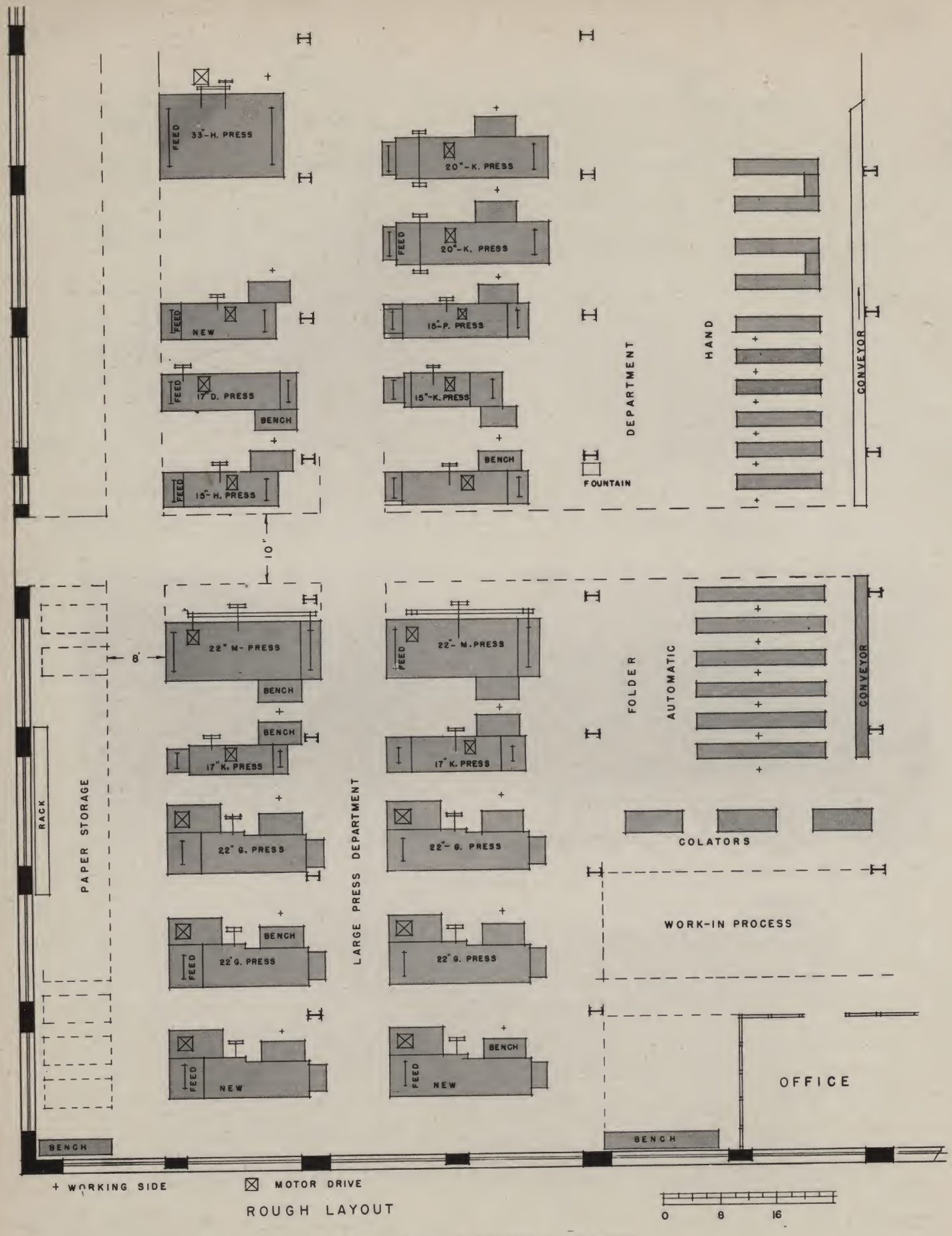


FIG. XI - ROUGH LAYOUT

Departmental Layout

With a new plant the arrangement can be such as is best suited to the processes, provided study is made of the requirements before the plant is designed. However, with an existing plant it becomes necessary to fit the processes in the best possible way. In either case, when preparing a rough layout, areas such as those mentioned on pages 17 and 18 (see Fig. VIII) can be used as a measure when selecting locations for the different departments. The department relation diagrams, as mentioned on page 14, Fig. VII, are helpful in this connection.

Decisions made during the rough layout are apt to be carried over into the finished layout. Thus it is essential to fix the relative location of the various departments at this stage of the layout.

As soon as the locations of the departments have been established the machinery and equipment can be fitted into the areas allotted to each department. The tabulations and other information described on pages 7, 9 and 13 under "Survey of Work" and "Data Needed" are an aid in doing this.

When laying out a department an arrangement which follows the sequence of operations in the case of production shops, and one which follows the grouping of machines by classes of work in the jobbing shop, and oftentimes a combination of these will produce a satisfactory layout. Even in a jobbing shop the work center idea can be used to advantage. With the present methods of ventilation and the newer types of processing equipment, operations which formerly were considered necessary to place in rooms apart from the regular flow of the work can usually be located so as to allow for the natural sequence. This, coupled with adequate work-in-process areas, conserves movement and sets up conditions which permit the use of handling equipment.

However, conditions vary when making a layout. Each case needs to be judged on its merits, weight being given to a balance between the practical and the ideal. Although the underlying principles may be the same, the conditions to be met vary according to industry, quantity of items to be produced, and the frequency of style changes.

In the making of the layout there are also objectives to be met:

1. Provision for the production of goods at minimum cost commensurate with quality.

2. Provision of a workplace in which the product can be made in such a manner as to stimulate high output and minimize fatigue.

The extent to which adequate building facilities, such as exhaust systems, heating, ventilation, air conditioning, lighting, noise reduction, wall coatings, floor surfaces, drives, material-handling devices, work-in-process areas, lunchrooms, locker rooms, first-aid and medical rooms are provided, often has a direct bearing on the high output of quality products. This can be beneficial to both employee and employer. It is advantageous to consider such features when making the rough layout, as it is often more expensive to provide for them after the installation of equipment is made. Also, it is well to know which, and to what extent, these facilities are necessary to the particular problem at hand.

Heating, ventilation and air conditioning are closely allied and, when treated as one, the result obtained may be more satisfactory than when taken separately. All of these relate to temperature, humidity, cleaning, and circulation of air.

When designing a system for the handling of air, conditions need to be such that the work space is comfortable, but in keeping with the requirements of manufacturing and storing the products. Some processes need high room temperature, and others, low. Similar conditions apply to relative humidity. Refrigeration has a place in the making of some products.

There is certain equipment (furnaces, spray booths, drying ovens, polishing wheels, etc.) which require exhaust systems for the removal of dust and fumes. In the removal of these, large quantities of air may be exhausted from the room. It is therefore necessary to make provision for replacing the air which is removed; also for heating the incoming air in the winter and possibly cooling it in the summer. Otherwise adverse comfort conditions may result.

Where ventilation is poor -- such as insufficient or too much air movement -- employee efficiency decreases and the quality of the work suffers.* If there is insufficient air movement or infrequent air change the temperature of the room may go up above the comfort level. On the other hand, where there is too much movement of cool air, discomfort from the opposite angle may develop. Thus illness and absenteeism are increased. Production falls off in like manner with a corresponding loss of employee earnings.

Where employees are called upon to work in the neighborhood of doorways which are frequently opened and closed to provide for the movement of materials, such as at shipping and receiving docks, it is essential that the door arrangements which form the air locks be such that both sets of doors will not be opened at the same time. This is particularly true of shipping and receiving docks on the north and west side of the building, for this is the direction from which the cold naturally enters the building in the winter. In the sections of the country where the winters are severe, it is preferable to have the shipping and receiving docks on the east and southerly sides of the building.

Lighting is an important factor in production. Clear vision helps to abate fatigue. Where the amount and quality of illumination is adequate, production results are likely to be more satisfactory than otherwise. Then, too, different eyes vary in the amount of light required to do a specific task. Also, some tasks require more light than others. The age of the person needs to be considered in the amount of light required. Sometimes so-called defective eyes are better suited to certain specific tasks than so-called normal eyes.**

With fluorescent lamp installation it is customary to use large amounts of light for general illumination. This, with the proper selection of colors on equipment, ceilings, walls, and, in some cases, floors, aids performance and safety. The general appearance of the space is also improved. Individual lamps at or on the machine may be needed when an extremely large amount of light is required. In some instances portions of the machine are painted in colors which have a high reflective value so as to direct the light toward sections of the machine where work is being performed. Also, the bodies of machines are being painted with shades

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*"Air Conditions and the Comfort of Workers," Policyholders Service Bureau Metropolitan Life Insurance Company.

**"Industrial Psychology," by Joseph Tiffin - Prentice Hall, Inc.

which tend to reflect rather than absorb light -- however, in colors which are easy to keep clean. Where the color is such that the light is being reflected rather than being absorbed, the general appearance of the room is enhanced and a fuller utilization of light is gained. This also has a bearing on the safety factor.

Sound-absorbing materials have been used in some plants for reducing the noise level. Many of these have been incorporated into the ceilings and partitions. Others are placed under machines as padding. As sound-absorbing materials are more or less porous they are likely to collect dirt more readily than other surfaces. They lose their effectiveness when the pores become filled with paint or other substances. It therefore becomes a matter of judgment as to where to place absorbing materials, and how much to use. Some absorbing materials have a tendency to absorb light, which is important from an illumination viewpoint. As sound-absorbing materials are usually insulators against heat or cold, such materials forming a part of the ceiling and exposed areas can be made to serve a dual purpose.

Floor coverings are available to meet floor-covering requirements. In some industries the floor surfaces are called upon to withstand heavy rolling loads; in others only light loads are moved from operation to operation. The surface of the floor, therefore, should be of such texture as to make movement easy and, for processes where utmost cleanliness is required in the making of the product, the surface should be of a texture to minimize cleaning costs.

Floors such as those having wood or composition surfaces help to keep down the noise level, and are an advantage also where there are operations which require employees to stand for long periods. With wood floors of sufficient thickness it is easier to lag down the machines, which is an advantage where frequent rearrangements are necessary.

Where bare concrete floors are used it is essential to treat them to prevent dusting and to increase the wearing qualities.

Power drives are important to all industries, and group units are used where it is economical to drive groups of small machines. However, the trend is toward individual drives. This, in addition to providing flexibility, simplifies the moving where rearrangements are made.

With the individual drive there is less belting, etc., to collect and distribute dirt and dust. Also, with the individual drive there are fewer obstructions to lighting and conveyor systems, and safety hazards are minimized. Power wiring, when installed in the form of "Bus-Ducts," adds flexibility where there are numbers of machines which require frequent rearrangement.

Material handling devices cover a range all the way from the simple trays and tote boxes to the skids, pallets, trucks, roller conveyors, moving platforms, pneumatic tubes, etc. These, when selected to serve an objective, can simplify the handling required and reduce cost. Where adequate study is made of the receptacles (trays,tote boxes, etc.) into which the items being manufactured are to be placed, containers can be had which will simplify production control.

Factors affecting the design of the container are: Proper protection to the items to be transported; sufficient size to hold an economical lot, but of suitable size and shape for the employee to lift without strain; compartments so arranged

as to assist the employee in making assemblies or for transferring materials to be worked on in and out of the container.

The policy of standardization of the containers, tote boxes, skids, etc., will aid in reducing the total number of containers needed and conversely, reduce the amount of storage space required for empties. On the other hand, the size and shape of the container and the nature of the materials contained are factors in the type of equipment which is used to convey or transport items from one place to another. Some products -- for example, bottled goods -- can be shipped in the containers in which the glassware is received. Belt conveyors are placed above the assembly line and are used for transporting the empty cartons from the receiving to the delivery end of the line.

With a moving conveyor for transporting materials in and about a department or through a number of departments, close timing may be required in order to keep in step with the processing, otherwise the conveyor may become a storage device so out of balance as to interfere with the normal flow of the work. When designing for the installation of material-handling devices it is important that they be laid out in such a way as to interfere as little as possible with the trucking aisles and the work areas, otherwise they may constitute safety hazards and impede the movement of trucks. Where possible it is advantageous to place conveying devices in positions where it is relatively easy to keep the devices clean, bearing in mind the safety angle.

Federal, State and local regulations must be met when constructing new plants or remodeling existing ones. These are the building codes which regulate the construction features. There are also health and sanitary codes relating to ventilation, washrooms, locker rooms, etc.*

AISLES AND WORK-IN-PROCESS AREAS

In making a new layout there is an opportunity to provide adequate work-in-process areas and aisles for the movement and storage of materials which are waiting between operations as they flow through the plant. If sufficient area is provided for these and at the proper intervals, in accordance with the manufacturing sequence, the over-all handling of materials through the plant can be kept to a minimum and congestion curtailed. Where there is sufficient space to provide for holding the work while it is waiting between operations there is less likelihood of accidents, and the plant presents a more orderly appearance. However, there are certain stages in work where it may be advisable to route to parts storerooms such items as are made up on stock orders and drawn as needed.

It is also advisable to allocate sufficient space at the machines to maintain work far enough ahead so that the operator is not called upon to seek materials too often. Then, too, allowances need to be made for the work stands, scrap boxes, die and tool racks, pallets, stools, etc., and for space the workmen require in operating the machines.

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*See "Washroom and Locker-Room Facilities," Policyholders Service Bureau, Metropolitan Life Insurance Company.

Similarly, sufficient space is required for placing work on which the operation is completed, such as tote boxes, skids, etc. Of course, the amount depends to a degree on the methods of transporting.

SYMBOLS AND ENGINEERING DATA

The following is a list of references to works giving symbols and engineering data:

Heating, ventilating, and air-conditioning (including piping and plumbing) - "Heating, Ventilating and Air Conditioning Guide"
Refrigeration - "Refrigeration Data Book"
Power - Electrical Engineers' Handbooks
Lighting - " " "
Power Drives- " " "
Material Handling - Mechanical Engineers' Handbooks
Construction - Architect and Builders' Handbooks

FINISHED LAYOUT

In all probability an ideal layout must be sacrificed for one which will incorporate the majority of the necessary considerations. The final layout will result in a compromise between the ideal and the numerous conditions which are inherent in the whole problem balanced against the cost, the savings, the manufacturing efficiency, and the desired standards of working conditions.

The finished layout, in the main, will be the incorporation of the work done in preparing the rough layouts into finished drawings. In a small layout it may be permissible to reproduce the rough layout photographically.

For means of identification the finished layout should carry serial numbers, one for each machine or piece of equipment. These are the equipment classification numbers, insurance numbers, or special numbers assigned in connection with the arrangement.

Before the finished layout is issued it is customary to prepare a cost estimate of what is involved, including contemplated economies, prior to receiving the management's approval. Approval of the project is signalized, in some cases by initialing the finished layout and in others by signing a formal authorization. It is good practice to obtain signatures of the department heads and others for whom the work is being done, as well as of top management and those responsible for the engineering. This tends to crystallize opinions and prevents differences when the work is actually being installed. Figure XII illustrates a finished layout. Figure XIII illustrates others.

After management has given its approval, construction drawings showing all the details necessary for the construction organization are prepared.

CONSTRUCTION DRAWINGS

In the main construction drawings show the electrical work, sheet metal work, carpenter work, masonry, millwright work, plumbing, heating, piping, and structural changes incidental to the project. (See Fig. XIV).

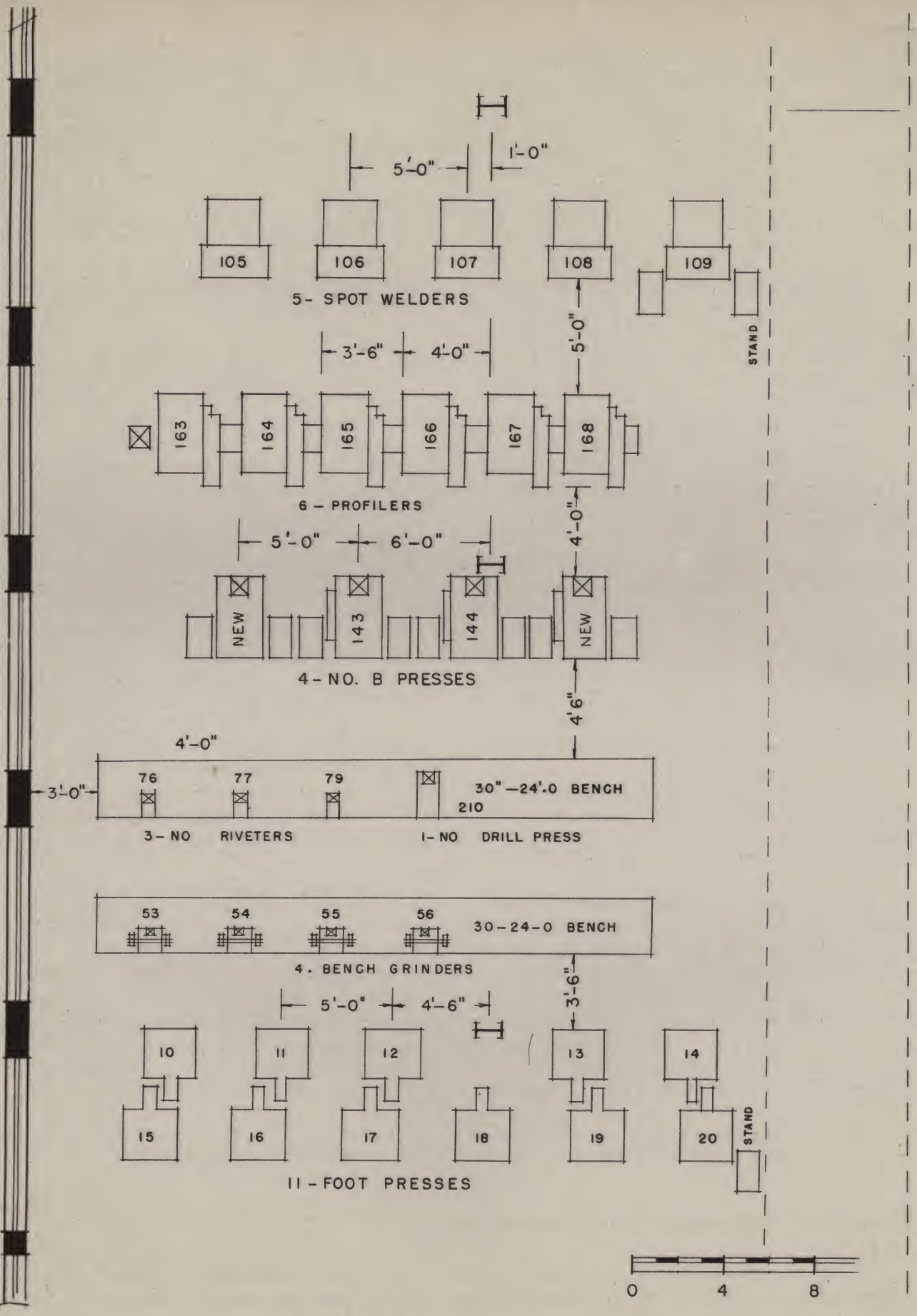
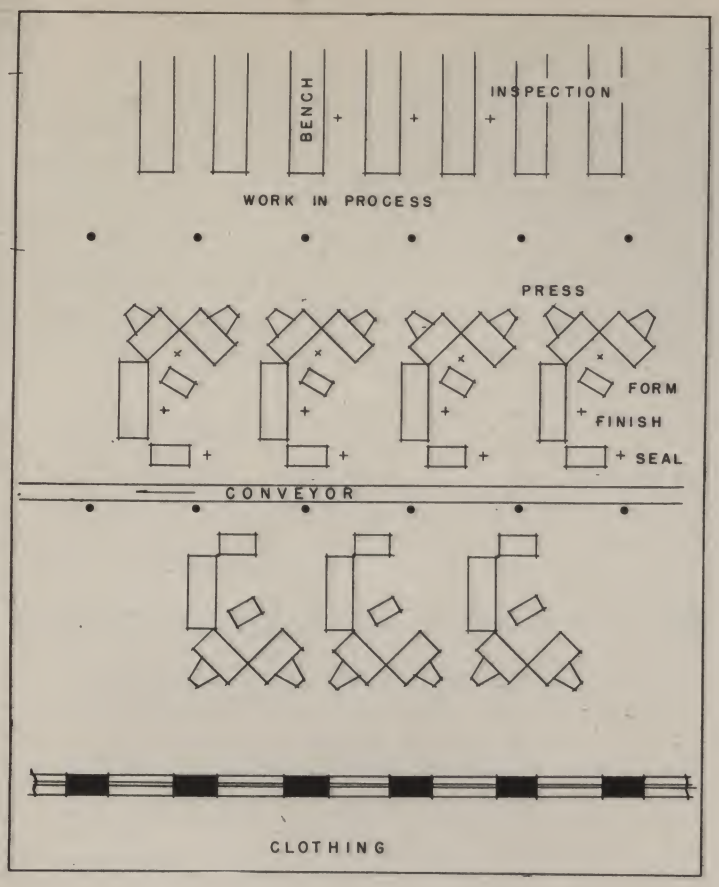
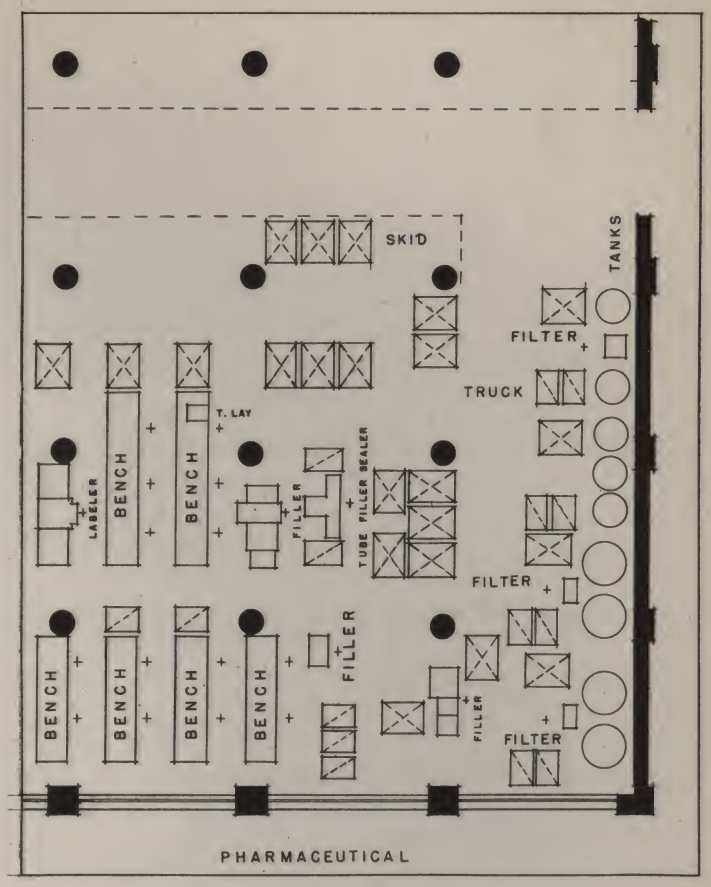
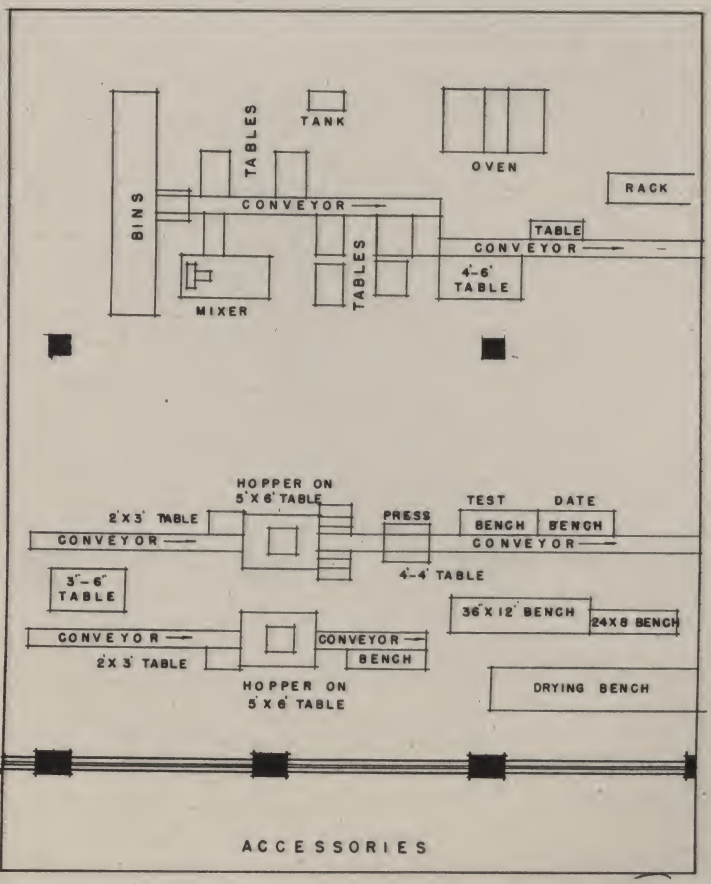


FIG. XII - FINISHED LAYOUT







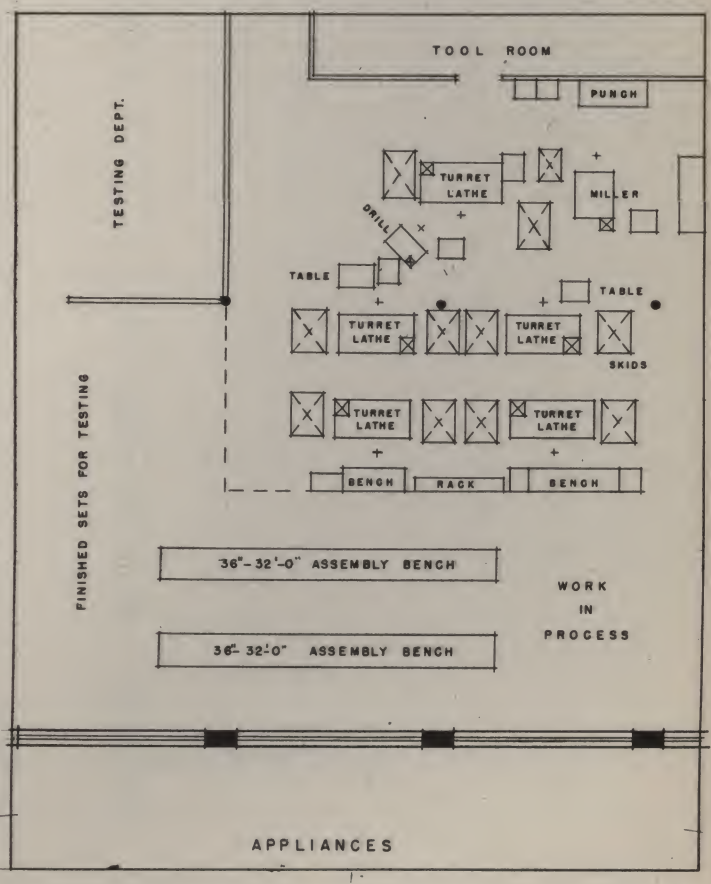
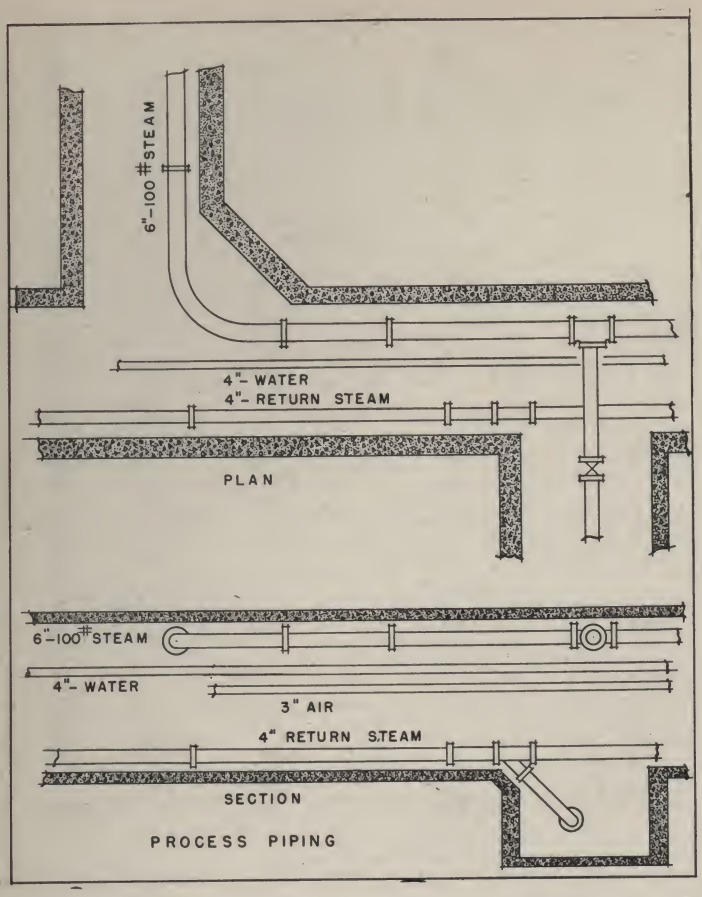
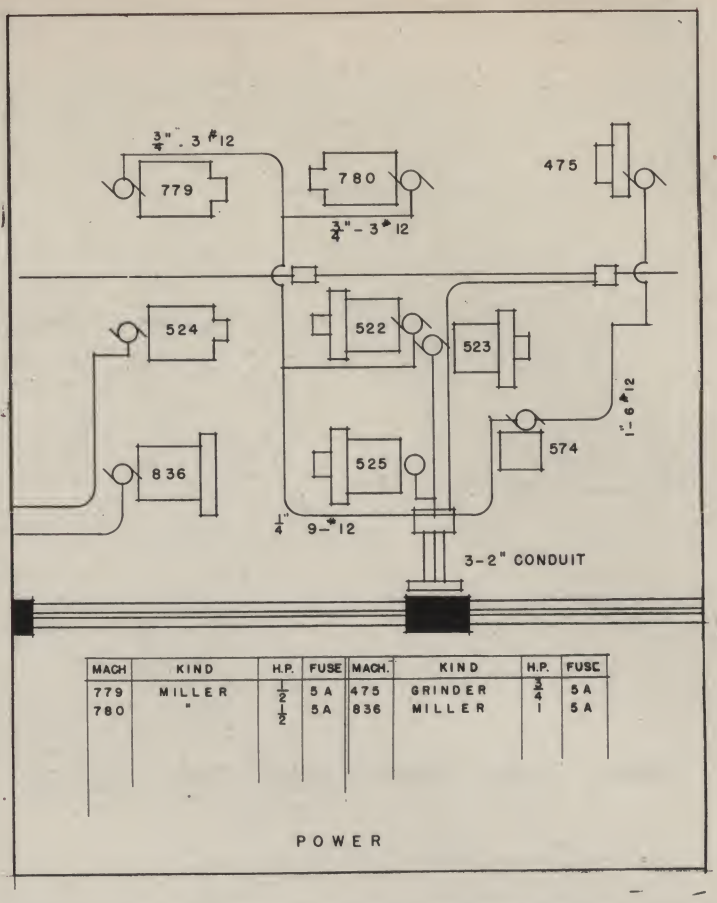
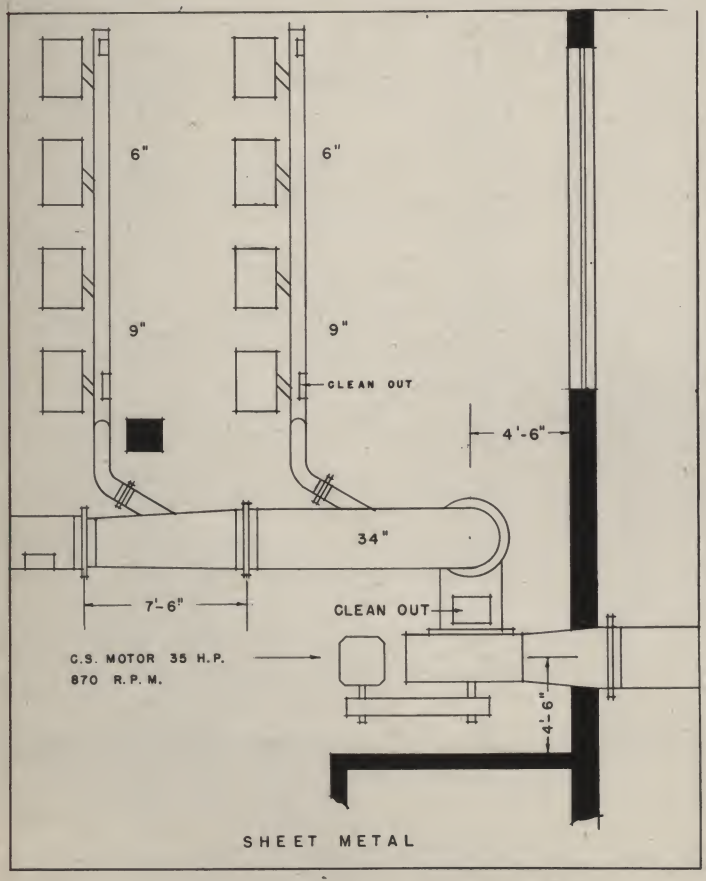


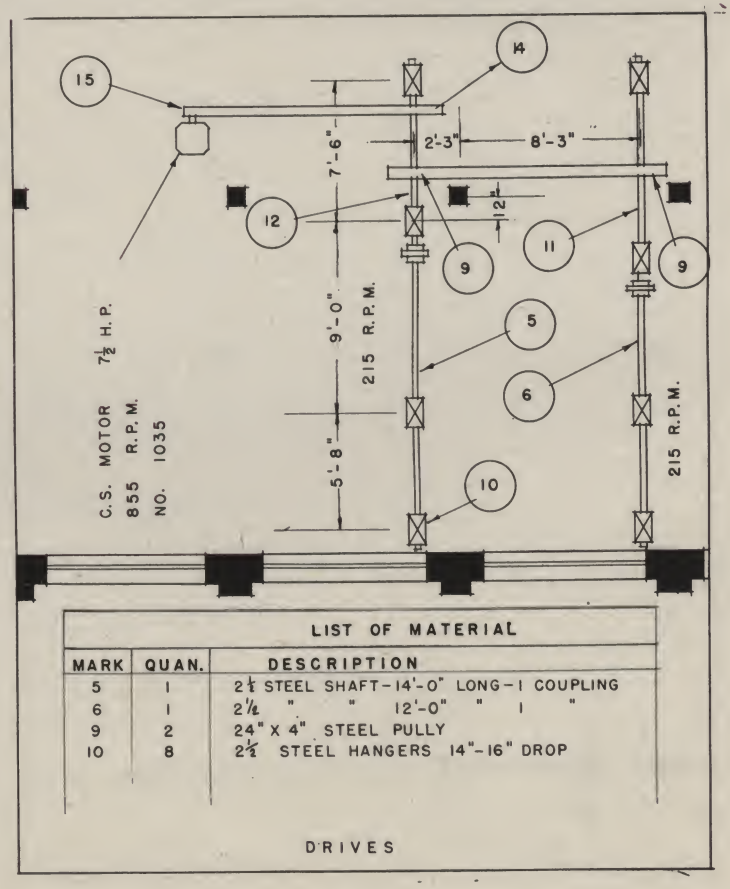
FIG. XIII - LAYOUTS





MACH	KIND	H.P.	FUSE	MACH.	KIND	H.P.	FUSE
779	MILLER	1/2	5 A	475	GRINDER	3/4	5 A
780	"	1/2	5 A	836	MILLER	1	5 A





LIST OF MATERIAL		
MARK	QUAN.	DESCRIPTION
5	1	2½ STEEL SHAFT-14'-0" LONG-1 COUPLING
6	1	2½ " " 12'-0" " 1 "
9	2	24" X 4" STEEL PULLY
10	8	2½ STEEL HANGERS 14"-16" DROP

FIG. XIV - CONSTRUCTION DRAWINGS

0 4 8

Some companies do their own construction work and others arrange for this through outside contractors. Where the latter are involved it is customary to prepare detailed specifications covering the work. These and the drawings form the basis for bids and proposals for carrying on the work. Regardless of who performs the work it is essential to have complete drawings covering sufficient detail to enable the work to be carried on with full knowledge of requirements and with dispatch, otherwise questions will arise during the installation which may delay the progress of the work or materially increase its cost.

MOVING MACHINERY AND EQUIPMENT

With adequate finished layouts and construction drawings, mentioned above, it is possible to prepare the space into which it is planned to set up the production machinery, equipment, etc., well in advance of the move. This, however, requires sufficient planning, scheduling, and coordination so that the various sections can be moved in logical order, thus holding delays in production and loss in output to a minimum. In many instances the actual moving can be carried on during the working hours. To facilitate the moving specially designed underslung platform trucks that can be lowered to the floor level are used, particularly if the change takes place within the same plant. Machines of moderate size can be operated up to the time of moving. The operators can then accompany the machines to their location and continue work as soon as the installation is completed.

As an aid to the installation of machines and equipment, an outline of each can be made on the floor of the space which the machines are to occupy. Transit and chalk line are used for this purpose. The identification serial numbers mentioned on page 9, corresponding to those shown on the finished layout, are inscribed on the floor within the outline of the machines or equipment. This is a help to the moving men in placing the machines in their designated spaces. Tables, racks, stools, etc., used by the machine operator in its operation, bear corresponding identification numbers.

In the schedule arranged for the move a close tie-in with the production organization is essential, so that a plan can be developed which will result in the least interference with production. The large machines and equipment which require time for installation are usually moved first.

In addition to the preparation of space for the new arrangement so that it will be in readiness when the move actually takes place, instructions and designations relating to the routing of products to the new location -- that is, changes in operation lists, transportation schedules, also instructions relating to the egress and exit of employees, assignment of lockers, reassignment of parking spaces and other employee facilities are needed.

FACTORY PLANNING AND LAYOUT is one of a number of studies issued by the Policyholders Service Bureau. It is typical of one phase of a program of service provided for companies that insure their employees under Metropolitan Group policies.

For many years the Metropolitan's health publications and services have been helping its policyholders keep well. With the growth of Group insurance came demands for special information -- first on problems relating to the health and safety of employees, then to other phases of industrial relations and on problems of general management.

The Metropolitan accepted these service opportunities as a matter of good business practice. The health and safety of employees is directly reflected in the company's claim experience. Assistance on other types of business management problems helps safeguard premium income by acquainting Group-insured companies with methods and practices that have resulted in more profitable operation and more stabilized employment in other organizations.

When the information gathered for a particular Group policyholder is believed to be of wide interest, it is put into suitable report form and offered to Group-insured companies generally. The present report is typical. Some other reports that have grown out of investigations made by the specialists who comprise the staff of the Policyholders Service Bureau are:

OFFICE PLANNING AND LAYOUT

AIR CONDITIONS AND THE COMFORT OF WORKERS

WASHROOM AND LOCKER-ROOM FACILITIES

LUNCH ROOMS FOR EMPLOYEES

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Policyholders Service Bureau
Metropolitan Life Insurance Company
One Madison Avenue
New York 10, N.Y.

Jackson

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Policyholders Service Bureau
Metropolitan Life Insurance Company

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